SINGER
METRICS DIVISION

Sensitive Research* INSTRUMENTS

*A Trademark of THE SINGER COMPANY

ELECTRICAL MEASURING STANDARDS

Since 1927, *Sensitive Research* engineers have established and maintained a tradition for designing and producing dependable high accuracy electrical measuring instruments. The product line today, ranges from portable and panel type indicating instruments to the most sophisticated laboratory standards. Calibration of all *Sensitive Research* instruments is traceable to the National Bureau of Standards where applicable.

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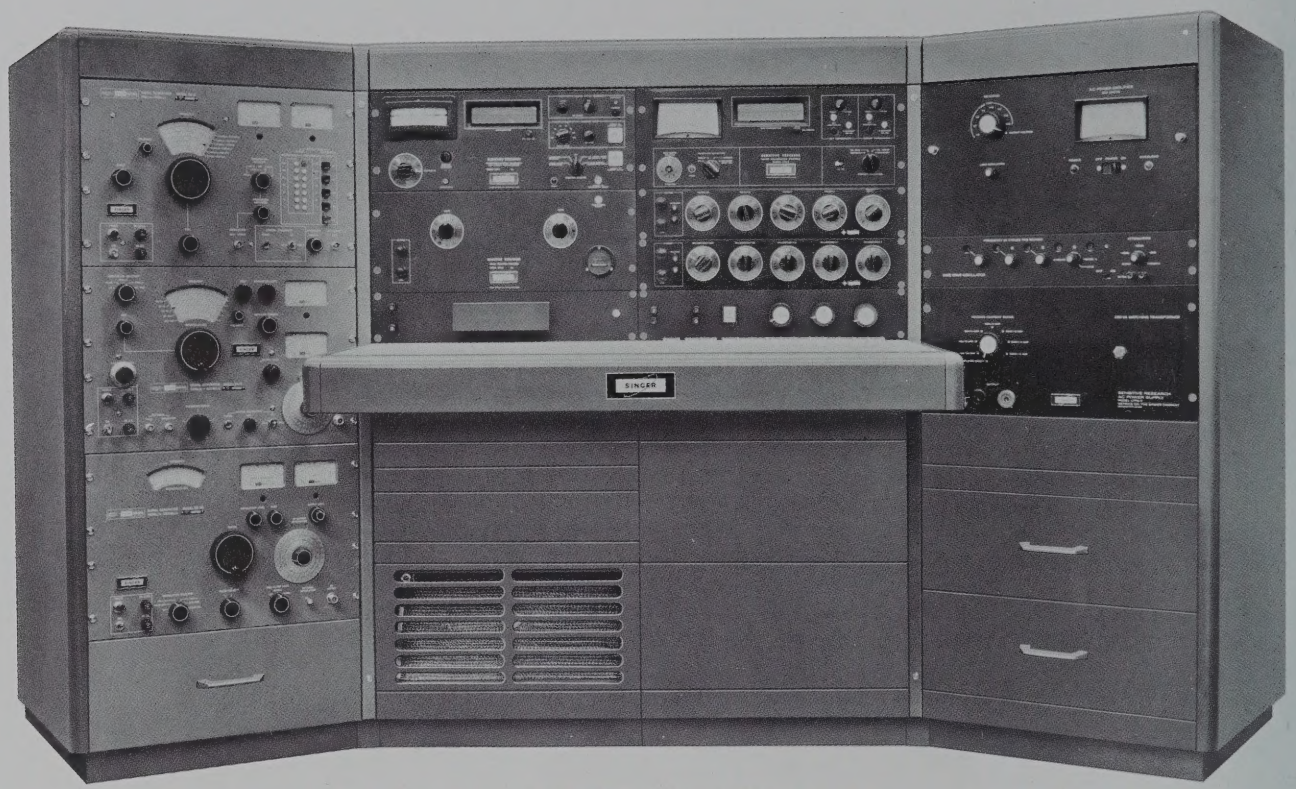
THE SINGER COMPANY · METRICS DIVISION

Panoramic · Sensitive Research · EMPIRE · Gertsch

CALIBRATION CONSOLES AND SYSTEMS



Calibration Console Model LTU-1

The *Sensitive Research* instrumentation line offers a wide selection of standard and special calibration systems comprised mostly of instrumentation manufactured within the Metrics Division. *Sensitive Research* instrument engineers have been designing respected DC, low frequency electrical standards since 1927, and this capability has recently been augmented by the addition of the *Panoramic, Empire* and *Gertsch* instrument product lines, enabling measuring systems up to 1000 Mc/s. So broad is the coverage of catalog items produced by the Metrics Division that a special console tailored to the users individual requirements, very often consists mainly of readily available "off the shelf" instruments. The purchaser has the advantage of receiving equipment with known and proven performance characteristics at a price that is close to the total of the individual instruments if bought separately.

Model LTU-1, pictured above, is indicative of The Singer Company capability in the systems field. It consists of three signal generators covering from 50 Kc/s to 1200 Mc/s, an A-T voltmeter, micropotentiometers, coaxial thermal converters and heavy current thermoelements, covering from 1 μv to 500 v up to 1000 Mc/s and 2 ma to 100 amps up to 20 Mc/s (See Model MPT, CTC, ATV, TX, T on page S3), an RF readout system and micropotentiometer calibrator (See Model RFS page S3), an AC/DC Calibration Console and low distortion AC source for fast measurements from 200 μv to 1100 v and 0.2 μa to 11 amps (See Model LTC-2 and LTPS-11 page S4) and appropriate DC sources remotely controlled and programed. Power sources have interlocking controls and thermoelements have automatic overload protection to safeguard operation.

Model LTU-2 is an integrated system of Metrics Division manufactured instruments specifically for the calibration of VTVMS, signal generators, micropotentiometers and sampling scopes, and the checking of receiver sensitivity. In operation, 10 micropotentiometers, with NBC traceability, are employed as standards to furnish calibrated outputs from 1 μv to 3 v up to 900 Mc/s. The micropotentiometers are standardized on DC prior to usage on AC. A signal generator feeds a micropotentiometer which in turn is used to standardize an *Empire* NF-105 field intensity meter and PA-210 *Panadaptor* unit employed as a transfer standard in actual calibration. PA-210 provides visual readout and a better signal to noise ratio at low levels. This console is similar in concept to the unit being employed at NBS Boulder as the National Reference Standard.

Inquiries are invited on special calibration and measuring systems.

DC TO 1000 MC

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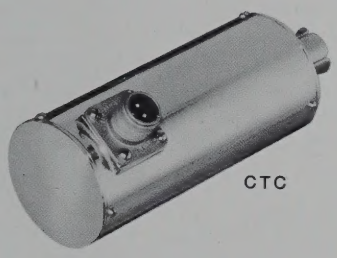
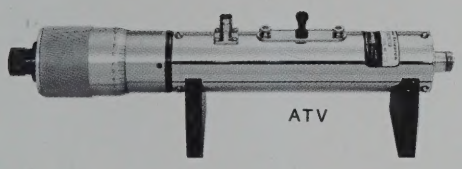
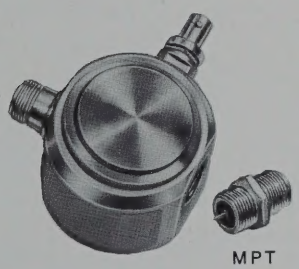
RFS



CTC



ATV



MPT

T

T (mounted)

RF Calibration System

Model RFS and accessory instruments, is a DC-RF calibration system featuring "state of the art" accuracies from 1 μv to 1125 v and 0.5 ma to 100 amps, at frequencies up to 1000 Mc/s. Basic console consists of two 19" rack panel mounted modules, Model RFS-1, a high resolution readout system to determine AC-DC differences or frequency influence, and Model FLH-1, an AC-DC transfer standard having a range of 1.5 to 1125 v with an accuracy of $\pm$0.01% up to 30 Kc/s and $\pm$0.02% up to 50 Kc/s. Current shunts available for use up to 10 amps. Model RFS-1 module is designed for rapid readout of true rms, RF sensing devices such as micropotentiometers, A-T voltmeters, coaxial thermal converters, thermoelements and other transfer instruments. Consists basically of a $\pm$0.5% accurate millivoltmeter, a Lindeck potentiometer with 14 fs ranges from 20 μv to 1 v, and a high sensitivity, oil damped galvanometer. Micropotentiometers can be calibrated on DC prior to AC usage, reducing to a minimum errors due to temperature, thermoelement overloads, etc. Thermal converters are suitable for calibration by NBS.

Coaxial Thermal Converter

Model CTC is a coaxial AC/DC thermal converter for making true rms RF voltage measurements from 0.25 to 200 v (200 ohms/v), up to 100 Mc/s. Construction is made in accordance with a design of F. L. Hermach and E. S. Williams (NBS, Washington, D.C.). A UHF thermoelement, having less than 0.01% AC-DC differences, is used as the converter. The heater of the thermoelement is connected in series with a low reactance film type resistor which terminates in a G.R. type 874-P858 coaxial input connector. The thermoelement junction output is fed thru a two-pin AN10SL connector. Guaranteed to be certifiable to the following NBS Boulder system accuracies: $\pm$0.02% DC and 6 cps to 50 Kc/s; $\pm$0.1% DC and 6 cps to 10 Mc/s; $\pm$0.2% DC and 6 cps to 30 Mc/s; and $\pm$1.0% DC and 6 cps to 100 Mc/s.

A-T Voltmeter

Model ATV is an adjustable waveguide-below-cutoff attenuator for the true rms calibration of RF voltmeters from 0.2 to 500 v at 10 to 1000 Mc/s. Construction is based upon an NBS design by M. C. Selby and L. F. Behrent. RF power is coupled to a UHF vacuum thermoelement by an output (movable) electrode. *Resolution is 0.0001" per division* and each division is divided by a vernier scale. Accuracy guaranteed to be within $\pm$1% of NBS figures.

Micropotentiometer

Model MPT is a true rms calibrated source of AC/DC microvoltages from 1 μv to 3 v (5 to 100 ma drain). Application is for checking receiver sensitivity, calibrating signal generators and sampling scopes, and making associated RF measurements to 900 Mc/s. Based on a design by Myron Selby of NBS. Construction is to specifications put out by Metrology Dept., Bureau of Naval Weapons Representative, Pomona, Calif. (K. H. Klarer). Micropotentiometers of this design are presently being employed by NBS, Boulder as the National Reference Standard. Guaranteed to be within $\pm$1% of NBS test results for 1 year. Present NBS uncertainties are $\pm$2% from 10 to 100 Mc/s, $\pm$3% from 100 to 500 Mc/s and $\pm$5% from 500 to 900 Mc/s.

Thermoelements

Model T are vacuum thermoelements with normal current ratings from 1 ma to 500 ma. For use up to 100 Mc/s. Can be supplied case mounted and/or with isolated heaters. DC reversal as low as $\pm$0.01%. Accuracy is dependent on frequency range and type. Model TX contact type thermoelements are mounted in air for heavy current measurements from 1 to 100 amps.

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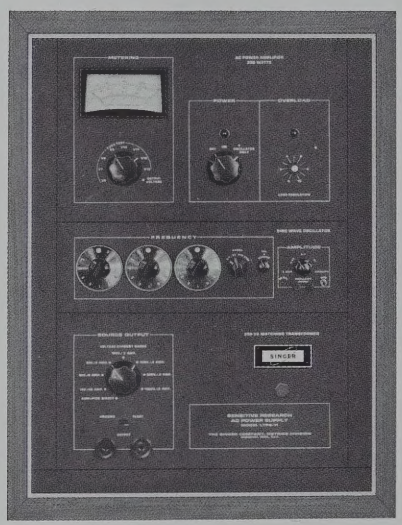
CALIBRATION CONSOLES AND SYSTEMS

LTC-2

AC/DC Calibration Console

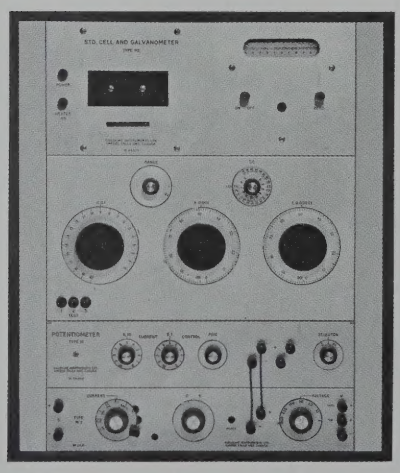
Model LTC-2 is a new current/voltage calibration standard featuring high speed operation from DC, 7 cps to 25 Kc/s over a range of 0.2 mv to 1110 v and 0.2 μa to 11.1 amps. Readout is in "% error" or actual values; resolution is 6 digits in steps of 1 mv on voltage and 5 digits in steps of 100 μa on current (except below 100 mv, 5 digits in steps of 10 μv, and below 1 ma, 6 digits in steps of 0.001 μa). Accuracy is $\pm$0.035% of reading on voltage and $\pm$0.05% of reading on current. A double element thermocouple reference circuit with better than 0.01% stability per hour reduces operating time and permits direct AC readings without frequent AC-DC transfers. Thermoelements are automatically protected for 25,000% overloads. An audio alarm system immediately calls the operator's attention to the presence of an overload. An adjustable self-contained voltage standard has long term stability (1 yr.) of 0.01% or better. The galvanometer, which also serves as the calibrated "% error" indicator, is oil damped and relatively free from the effects of vibration. Resolution is constant for all ranges and can be set at 0.002% mm division. Galvanometer has a clearly defined light spot and front panel zero control. Console designed for 19″ rack mounting or bench use in a shielded formica case. Modular construction permits easy maintenance. Size is only 16″ x 20 1/2″ x 16″ high when bench mounted.



LTPS-11

Ultra Stable AC Power Supply

Model LTPS-11 is a 200 watt AC power source designed especially for use with the Model LTC-2 calibration console, Model RFS RF calibration system and Model FLH AC/DC transfer standard. It features wide range (0 - 17 amps rms, 0 - 1500 volts rms), low distortion (0.05%), variable frequency (10 cps to 100 Kc/s) and excellent short term amplitude stability (0.005%). Available in a formica case for bench use or for standard 19″ rack mounting.



MR

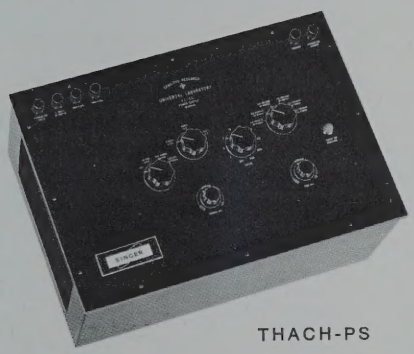
DC Potentiometer System

Type MR is a low cost, high accuracy precision DC potentiometer system modularized for standard 19″ rack mounting. Each module may be used independently. When employed together as a system, inter-connection facilities are provided to speed up operation and reduce dependence on user technique. It consists of the following instrumentation: (1) A 5 figure, 3 dial shielded potentiometer having measuring ranges of $-$10 μv to 2 v in steps of 10 μv and $-$1 μv to 0.2 v in steps of 1 μv. All positions on the switches are individually calibrated points and there is no slidewire in the circuit. Accuracy is $\pm$(0.003% of reading + 1 μv) on X1 range and $\pm$(0.003% of reading + .5 μv) on X.1 range. Thermals are less than 0.5 μv. (2) A switch controlled current/voltage range extension unit made up of seven 0.01% accurate, 4 terminal standard resistors (0.01Ω to 10,000Ω) enabling measurements from 0 - 10 amps and an overload protected 0.01% accurate volt ratio box enabling measurements from 0 - 1000 v. (A 500 v multiplier is available for measurements up to 1500 v.). (3) Three portable saturated cells installed in a $\pm$0.03°C constant temperature enclosure with solid-state temperature controller to provide a $\pm$5 PPM voltage reference. (4) A high sensitivity oil damped galvanometer with a double light spot. Size is only 24″ x 20 1/8″ x 12 5/8″ deep. Type MR is unique because of its size, cost and completeness. Traceability to NBS can be established directly via saturated standard cells and standard resistors. The potentiometer and volt ratio box can be self checked. The Model FLH AC/DC transfer standard and current shunts can be added to the system for AC measurements up to 50 Kc/s. *(See Page S-11)*

THACH

AC/DC "Self Checking" Volt-Amp-Milliammeter

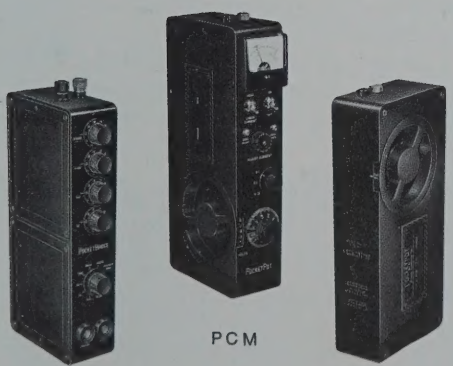
Model THACH is a 19 range, *self checking* AC/DC volt-amp-milliammeter. It is available in three combinations, all of which have the same full scale ranges and general performance specifications, but vary in the design of their *self checking* circuits. The combs. 1X and 3X contain an internal standard cell and galvanometer (battery operated, self contained). The ruggedized comb. 5X utilizes an internal 0.02% stable, solid state reference source (115v, 60 cps external source required). Pushbutton design permits easy "on the job" checking of scale linearity. 1000% manual (press to read) overload protection is provided (25000% automatic overload protection, with an audio alarm system, is optional). Accuracy is ±0.1% of full scale at *self checking* points and ±0.2% of full scale at all other points from DC and 6 cps to 4 Kc/s. Full scale ranges are 10 ma to 5 amps and 1 v to 1000 volts (100 ohms/v.) Ranges are overlapping permitting maximum accuracy and resolution since most readings may be taken at or near full scale where scale divisions are greatly expanded. Can be furnished wired for use with Model THACH-PS power supply to make it a convenient wide range calibrator.



THACH-PS

AC/DC Power Supply

Model THACH-PS is a general purpose AC/DC regulated power source that is designed for use with the Model THACH volt-amp-milliammeter. The controls of the power supply are interlocked with the Model THACH (when furnished for use with the Model THACH-PS) and power is automatically shut off when ranges are switched, reducing the danger of accidentally overloading the calibrator and/or the instrument under test. 75 w output enables the calibration of all electrical indicating instrument types within the capability of the THACH for DC and 60 cps (and 400 cps on special order). Input 90 to 135 v, 60 cps; 50-2500 cps from an external source can be plugged for operation over a broader frequency range. Resolution of the power supply controls is better than 0.05% for all ranges. Distortion is 2.5% or less; ripple normally does not exceed 0.5%. Size is 12¾" x 17" x 9" deep.



PC-R PCM PC-S

Miniature DC Potentiometer System

Model PC *PocketPot* instrument is a miniaturized DC potentiometer system for use as an infinite resistance calibrator and measuring instrument from 0 to 5.1 v. It has a self contained high sensitivity galvanometer and solid state adjustable voltage standard. It needs no accessory equipment to perform within its measuring range. Accuracy is ±0.05% of reading or ±0.5 mv, whichever is greater. Readout is direct and "in line". Ranges are switch controlled. Battery operated and does not require an external AC power source. Weight and size are such that it may easily be operated in the palm of the hand!

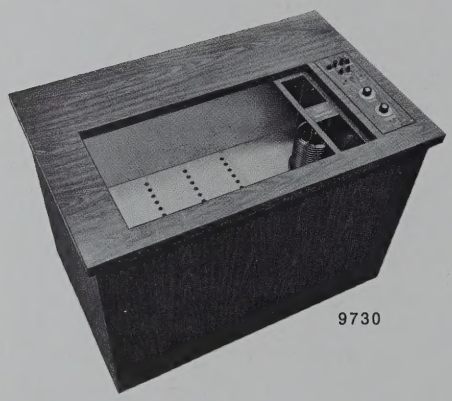
Model PCM is a 3 range (0 to 5.1 v, 0 to 0.51 v, 0 to 0.051 v) high sensitivity *PocketPot* instrument, with physical construction and other performance characteristics identical to the Model PC.

Model PC-S "plug-in" volt-current range extension box extends the total measuring range of either *PocketPot* instrument. Accuracy is ±0.05% of reading. Ranges are .5/5/50/500 ma; 1 amp; 5/50/500 volts.

Model PC-R "plug-in" wide range, portable Wheatstone Bridge adds the capability of making resistance measurements to the *PocketPot* instruments. ±1% accuracy from 0.1 ohm to 10 ohms and ± 2% to 9.999 meghoms. It can also be used as a portable decade resistance box.

9461

9460



9730

9770A

Galvanometers

Type 9460 Photocell Amplifier (formerly Type 5214) when used in conjunction with Type 9461 Secondary Galvanometer (formerly Type SR 21) is ideally suited for operation with DC bridges and high accuracy, high sensitivity, precision DC potentiometers. The overall sensitivity of this galvanometer system, when connected for series feedback, is normally not less than 350,000 mm/μa at maximum gain and when connected for parallel feedback, not less than 56,000 mm/μv. The amplifier contains a primary galvanometer (liquid filled to reduce the effects of mechanical vibration) which differentially illuminates two opposed barrier layer photocells. Its non-electronic circuit assures a noise free, stable operation. The photocell current resulting from an out of balance condition is used to deflect the rugged Type 9461 secondary galvanometer. Aluminum case. Size is 6″ x 6$^1/_2$″ x 14″ long. The primary galvanometer in the amplifier is available separately as the Type 5180. As an optional accessory a Type 9460A Thermal Compensator (formerly Type 5214A) is available. It can introduce 0 to 2 μv into the amplifier input to balance any stray thermal emfs in the measuring circuit.

Type 9460 Secondary Galvanometer receives all its sensitivity from the amplifier. Period is approximately 2.5 sec. A 4 position sensitivity switch gives multiplying factors of 1/.1/.01/.001. Scale is 24 cms long and marked 120-0-120 in mm division. Fitted with a removable polaroid filter to enable glare free readings. Size is 13$^3/_8$″ x 10$^3/_8$″ x 7$^3/_{16}$″ high. Formica case.

Type 9450 (formerly Type SR4) is a general purpose, high sensitivity, oil damped galvanometer for use with DC potentiometers and those applications that require a vibration free, low thermal light spot null-detector. Suspension resistance ranges from 3 to 550 ohms for maximum sensitivities. Designed in a formica case for bench use or in an aluminum panel for rack mounting.

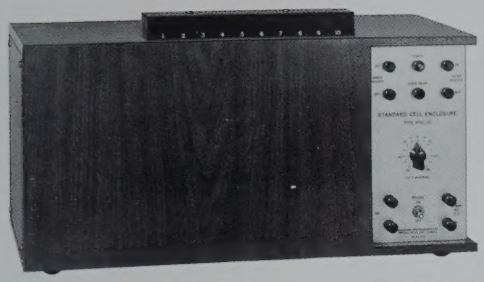
Type 9411 Light Spot Galvanometer is a vibration free, high sensitivity null detector designed for vertical panel mounting and is ideally suited for inclusion in OEM applications as well as for "in plant" test equipment.

Constant Temperature Oil Bath

Type 9730 series of oil baths are thermostated at one fixed temperature setting or adjustable for a number of fixed points between 20°C and 40°C to check temperature coefficients of resistors. Solid state temperature controller regulates bath to ±0.05°C. Thermistor bridge has capability of detecting ±0.01°C variations in temperature control. Gradients in bath less than ±0.01°C. Construction features are all copper terminals, 34″ x 17″ x 13″ deep (ID) stainless steel insulated tank, 14″ of formica bench space slanted toward bath, motor driven impeller for optimum oil circulation (mounted underneath tank) and cooling tubes to lower temperature of bath below ambient.

Constant Current Source

Type 9770A, when referenced against an external saturated cell, supplies 1 ppm stable DC currents from 10 to 100 ma (±10 ppm when using an internal reference) for line charges of 50 to 125 vac and variations in load of 3500 ohms to a short circuit. Available voltage at the load terminals is 36 v maximum. Application is for use with DC potentiometers as battery replacements and in measurements involving gyros, accelerometers and other circuits requiring highly stable currents within its output range.



9152/P10

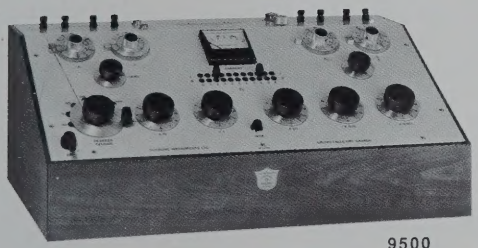
Constant Temperature Standard Cell Enclosures

Type 9152 series of saturated standard cell constant temperature enclosures are stable to ±0.01°C at a nominal fixed temperature from 28°C to 35°C (as required). Standard models house from 4 to 12 cells. Type 9152/P4 is a rugged, lightweight portable enclosure designed as a transfer standard for intercomparison with NBS and users lab. Designed to operate in extreme ambients; testing down to −20°C shows no deterioration in internal temperature control. Saturated cells contain porous partitions and can be shipped by commercial carrier. Accuracy guaranteed to 0.0001% with NBS figures. Power required: 110 v/60 cps or 12 VDC with automatic switchover in case of AC power failure. All standard cell enclosures feature a new patented solid state temperature controller. A bridge detection system, that eliminates a thermometer and absolute temperature as an accuracy factor, indicates variances in internal temperature to −0.001°C. Automatic cutoff of power to enclosure in event of overheating.

9152/P4

Direct Reading Thermometer Bridge

Type 9500 is a 6 dial resistance thermometer bridge that *reads-directly in temperature from −50° to +711.110°C!* Readings in resistance can be obtained down to −260°C, the lower limit of a platinum resistance thermometer. *Measurements are independent of lead length and variations in thermometer current! Most measurements are characterized by one man operation!* An invention of the Dr's. H. Preston-Thomas and T.M. Dauphinee of Canada's National Research Council, the bridge is designed to largely replace present day slow and cumbersome equipments (such as Smith and Mueller Bridges and potentiometer systems) in the calibration of thermocouples, liquid in glass thermometers, some types of resistance thermometers and the measurement of spot temperatures. Bridge accuracy is ±0.001% of setting. It uses a standard 25 ohm platinum resistance element as a sensor. Only external equipment necessary is a sensitive null detector (Type 9460 Photocell Amplifier and 9461 Galvanometer) and/or an amplifier (Type 9790) and chart recorder (capable of indicating the reading of the last 3 dials). Other features are thermal emfs eliminated by a single switch reversal, internal thermostated enclosure and complete autocalibration capability.



9500

Isolating Potential Comparator

Type 9800 is a precision DC resistance and voltage comparator employing an isolating potential circuit with a mechanical chopper (Type 9743, available separately) that generates less than ±0.02 μv of thermal emfs. Precision of comparison, depending upon differences being measured, can be a fraction of a PPM. It operates independently of lead resistance, as in potentiometric comparisons, and of current stability, as in Wheatstone bridge measurements. Applications include the comparison of nominally equal fixed resistances with each other (in the range of 0.01 to 10,000 ohms), fixed resistances with a variable resistance, decade resistance boxes step by step with a standard box, platinum resistance thermometer with the resistance of a variable 4 terminal resistor and the continuous difference in output emf of a standard thermocouple with the output of an unknown thermocouple. It is suggested as an accessory for the Type 9144 Dauphinee potentiometer to make precision temperature measurements. Freedom from lead resistance errors makes the comparator valuable for resistance thermometry in low temperature measurements and in applications where equipment must be remotely located. The voltage difference between the output of two thermocouples can be continuously plotted on a chart recorder as the temperature is raised and lowered.

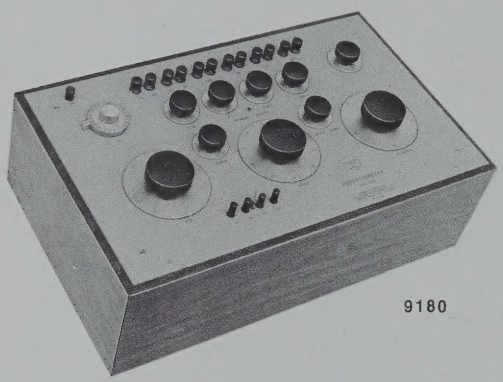
9800

COMMANDER* ELECTRICAL MEASURING

9144

Dauphinee DC Potentiometer

Type 9144 is a 4 dial, 6 figure DC vernier potentiometer constructed to a unique patented design by Dr. T. M. Dauphinee of Canada's National Research Council. Accuracy of 10 PPM of reading without correction curves is warranted for 5 years. Linearity of initial adjustment is guaranteed to better than 2 PPM. The Dauphinee potentiometer has compiled a superb 7 year history of reliable performance. (By early 1964 it was the basic standard in over 300 laboratories.) It was receiving NBS Certificates prior to the discontinuance of this practice. No other potentiometer has such wide application. In addition to being a superb measuring instrument it is: (1) A ±2 PPM accurate resistance comparator. (2) A saturated standard cell comparator that detects differences of ±0.1 μv. (3) A 100 PPM accurate variable 4 terminal standard resistor. (4) A constant temperature enclosure with two 10 PPM saturated standard cells, internally air thermostated at 28°C. (5) A temperature measuring instrument with resolution to 0.0005°C. (Especially designed for use with the Type 9800 isolating potential comparator). Measuring range is −10 μv to 2.101010 v in steps of 1 μv and −1 μv to 0.2101010 v in steps of 0.1 μv. Maximum generation of thermal emfs is 0.1 μv. Completely *self checking*. Separate galvanometer circuits to monitor standard cell emf while making potentiometric measurements. 5 galvanometer sensitivity keys including a reverse position. "In line" readout of standard cell emf on concentric dials. Completely shielded. No slide wire in circuit; all switch positions are individually calibrated. Switch contacts and terminals made of copper.



9180

Type 9180 is a 20 PPM accurate, 3 dial, 5 figure version of the Dauphinee Potentiometer. Design combines advantages of high and low range potentiometers in economically priced general purpose instrument. Measuring range of −10 μv to 2.10100 v with maximum resolution of 0.01 μv on X0.001 range. Completely *self checking*. Less than 0.05 μv thermal emfs on X0.001 range.

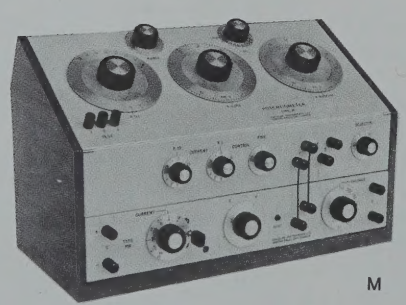
7 Figure DC Potentiometer

9120

Type 9120 is a 15 PPM accurate, 4 dial, 7 figure precision DC potentiometer with a single window readout and a resolution of 1 part in 20 million. Total measuring range of 2.099,999,9 v in steps of 0.1 μv is achieved without the necessity of switching ranges. Completely *self checking*. All positions on the measuring dials are individually calibrated steps (no slidewire). Measuring circuit switches are potential contacts only and do not carry current; switch contact resistance is, therefore, of no importance. Thermal emfs are less than 0.1 μv. 5 galvanometer sensitivity keys including a reverse position.

DC Microvolt Potentiometer

Type 9174 is a 2 dial, 4 figure DC potentiometer designed for low level measurements requiring ultimate in precision. Generation of thermal emfs is less than 0.01 μv. Total measuring range is −0.1 μv to 1010 μv with maximum resolution of 0.001 μv per step on X0.01 range. Linearity is 100 PPM of reading. Completely *self checking*. All switch positions are potential contacts only, contact resistance is, therefore, of no importance.



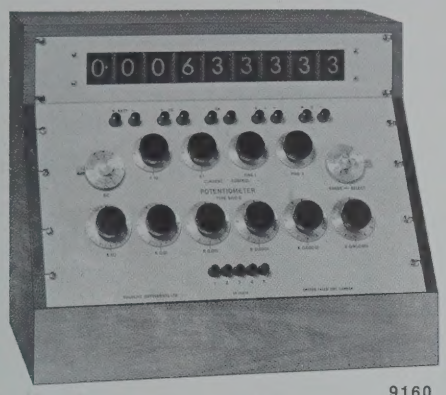
M

Compact DC Potentiometer

Type M is a ±30 PPM accurate, 3 dial, 5 figure potentiometer that incorporates many design features found only in higher priced instruments. Total measuring range is −10 μv to 2 v with a maximum resolution of 1 μv on X0.1 range. No slide wire in circuit, only individually calibrated switch positions. 3 galvanometer sensitivity keys. Maximum generation of thermal emfs is 0.5 μv. It is usually furnished as part of a system for bench use or rack mounting as described on page S-4.

SINGER
METRICS DIVISION

Sensitive Research* INSTRUMENTS
*A Trademark of THE SINGER COMPANY



9160

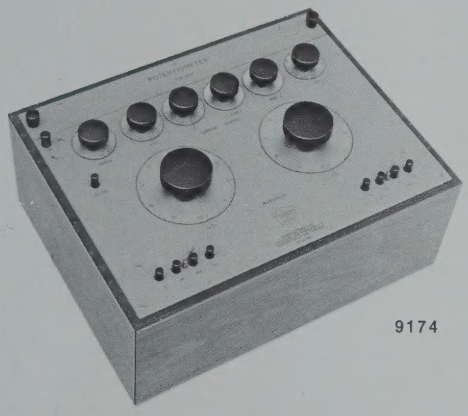
DC Potentiometer with Digital Readout

Type 9160 is a 15 PPM accurate, 6 dial, 6 figure DC potentiometer with provision for remote illuminated digital readout. Total measuring range is 0 to 2 v with maximum resolution of 0.01 μv on X0.01 range. Maximum generation of thermal emfs is 0.1 μv. Completely *self checking*: 5 galvanometer sensitivity keys with a reverse position. Available for portable use or standard 19″ rack mounting. Ideally suited for incorporation into a rack mounted AC/DC calibration system utilizing the Type 9700C volt ratio box, Type 9200 current shunts, Type 9460 and 9461 amplifier and galvanometer, Type 9152/4-R enclosure with 4 saturated standard cells and Model FLH-1 transfer standard.

SUMMARY OF COMMANDER POTENTIOMETERS

Type	Significant Figures (Below 1 volt)	Range Factor	Resolution	Ranges	Accuracy in % of Reading
9144	6	X1 X0.1	1.0 μv/step 0.1 μv/step	−10 μv to 2.101,010 V −1 μv to 0.210,101,0 V	± (0.001% + 0.5 μv) ± (0.001% + 0.1 μv)
9120	7	X1 only	0.1 μv/step	0 to 2.099,999,9 V	± (0.0015% + 0.1 μv)
4363D	6	X1 X0.1	1.0 μv/step 0.1 μv/step	−15 μv to 1.901,010 V −1.5 μv to 0.190,101,0 V	± (0.0015% + 1 μv) ± (0.0015% + 0.5 μv)
9160	6	X1 X0.1 X0.01	1 μv/step 0.1 μv/step 0.01 μv/step	0 to 2.100,000 V 0 to 0.210,000,0 V 0 to 0.021,000,00 V	± (0.0015% + 0.1 μv) ± (0.0015% + 0.1 μv) ± (0.0015% + 0.1 μv)
9180	5 Optional Range →	X1 X0.1 X0.01 X0.001	10 μv/step 1 μv /step 0.1 μv/step 0.01 μv/step	−10 μv to 2.101,00 V −1 μv to 0.210,100 V −0.1 μv to 0.021,010,0 V −0.01 μv to 0.002,101,00 V	± (0.002% + 1 μv) ± (0.002% + 0.5 μv) ± (0.002% + 0.1 μv) ± (0.002% + 0.05μv)
9174	4	X1 X0.1 X0.01	0.1 μv/step 0.01 μv/step 0.001 μv/step	−0.1 μv to 1010.0 μv −0.01 μv to 101 μv −0.001 μv to 10.000 μv	± (0.01% + 0.01 μv) ± (0.01% + 0.01 μv) ± (0.01% + .01 μv)
M	5	X1 X0.1	10 μv/step 1 μv/step	−10 μv to 2.00,000 V −1 μv to 0.200,000 V	± (0.003% + 1 μv) ± (0.003% + 0.5 μv)

All potentiometers have electrostatic and thermal shielding.



9174

High Sensitivity DC Amplifier

Type 9790 high sensitivity amplifier is designed for the detection, measurement and long term recording of DC signals from a fraction of a microvolt to 300 μv. It utilizes a low thermal chopper (Type 9744 available separately) as a modulator-demodulator that introduces less than 0.02 μv of extraneous signal into the output. Features are: (1) Immediate recovery from overloads of 1,000,000%. (2) 0.03 μv fs lowest range. (3) 0.003 μv stability over 24 hours. (4) Thermal emf compensation. Output is 1 ma into 1500 ohms or 1, 10 or 100 mv fs. Output resistance is 50 ohms. Response time is 2 to 5 seconds to 90% fs, depending on output filters. Internal calibration to ±5% accuracy.

9790

Standard Volt Ratio Boxes

Type 9700 series of thermostated oil filled master volt ratio boxes are constructed in accordance with NBS Research Paper 1419 by Selby and Gross. An important modification of the original design has been made by substituting circulating oil for still air to reduce self heating effects to a PPM or less, even after continuous duty at 1500 v. Solid state temperature controller and automatic overheat protection circuit provide maximum operational reliability. Guard circuit reduces leakage to a negligible factor. Accuracy is ±10 PPM of reading. Application is for use as a standard volt ratio box to check other volt ratio boxes or dividers, and as a direct voltage measuring instrument in a potentiometric system. Type 9700 has 16 taps from 0.15 to 750 v, Type 9700A, 21 taps to 1500 v; Type 9700B has 11 taps from 1.5 to 750 v, Type 9700C, 16 taps to 1500 v. Type 4281 series are smaller sized, lower priced ±0.01% accurate volt ratio boxes with ranges from 1.5 to 1500 v.

9700

ELECTRICAL INDICATING INSTRUMENTS

Sensitive Research DIAMOND PIVOT

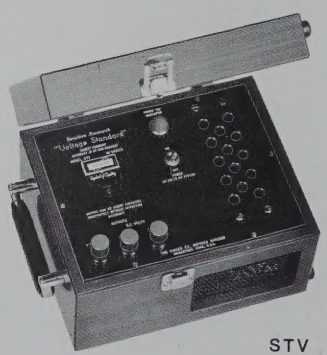
Sensitive Research instruments has been a synonym for fine electrical indicating instruments since 1927. Over 100 models of general purpose and special instruments, encompassing more than 4500 range combinations, are available as production and laboratory standards for measurement of current, voltage, power, magnetic field strength, core loss, ratio, frequency, resistance, form factor and similar quantities.

Sensitive Research electrical indicating instruments are available in several basic designs, such as permanent magnet moving coil, electrodynamometer, electrostatic and moving iron types — and in modifications of these designs by adding a thermal converter, solid state transducer, full wave rectifier or transformer coupling. Meticulous assembly and selection of components produce an instrument of the highest precision and stability. Diamond pivots and shock mounted sapphire jewels are employed in properly aged, strain free, moving coil mechanisms. Designs emphasize a low coil mass and strong restoring springs to achieve an above average torque to weight ratio. Cases are made of durable formica and rubber gasketed to provide a dust and humidity barrier. All instruments are individually calibrated and have hand drawn scales. Other significant features include automatic thermistor temperature compensation, automatic overload protection, grounded conducting window glass and lacquered scale plates that can be redrawn. All instruments are provided with data cards listing temperature corrections and maximum overload ratings. They conform to the specifications listed in ASA C-39.1 nad, MIL-M-16034B. Calibrations are traceable to NBS.

LE

Lindeck Microvolt Source

Model LE is precision DC microvolt source with 14 output ranges from 1 μv to 2 v full scale. Ideal for low level measurements. Maximum generation of thermal emfs is 0.05 μv. 6.3″ scale length. Resolution is 0.01 μv/division on 1 μv range. Accuracy is $\pm$ (0.35% of fs + .05 μv). Designed primarily for use in such applications as: (1) The intercomparison of volt ratio boxes, standard cells, and decade dividers. (2) The detection and measurement of thermal emfs and other DC signals in the microvolt range. Economically priced! Other low level measuring instruments are the *Commander* 9180 and 9174 DC potentiometers listed on page S8.



STV

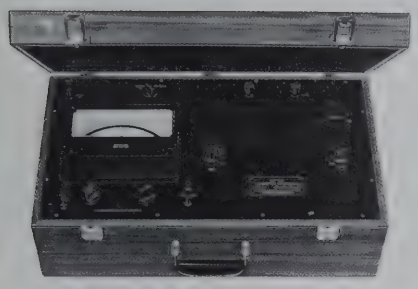
DC Voltage Standard

Model STV is a 100 PPM accurate solid-state DC voltage source for use as a reference standard with "null balance" devices such as potentiometers and other infinite impedance comparators. It is equivalent in accuracy and stability to unsaturated cells and superior in almost all other respects to both saturated and unsaturated types. Unaffected by vibration from transportation, short circuiting or operating position. Nominal outputs of 1 v and 1.0185 v. Multirange up to 7.5 v. 100 to 135 v AC 60 cps input. Adjustable in field to better than 10 PPM. Temperature coefficient less than 0.001%/C°.

RFVC

Radio Frequency Voltage Calibrator

Model RFVC is a thermocouple type electrical indicating instrument specifically designed for the calibration of VTVMS from DC, 5 cps to 10 Mc/s. Self calibrating on DC via a 0.05% accurate internal solid state voltage source. Automatic temperature compensation from 20° to 30°C. Accuracy is $\pm$0.5% of full scale on 0.1/1/3 v ranges and 1% on 0.01 v range. 3 v range can be used for measurements, others are output ranges only. Sensitivity is 200 ohms/v. 6.3″ scale length. 115 V, 60 cps input.



FLH

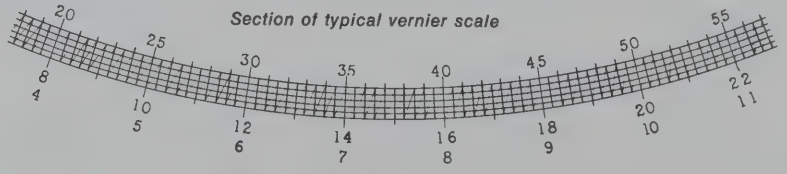
AC/DC Voltage Transfer Standard

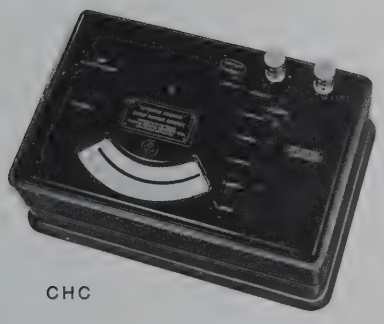
Model FLH is a precision, portable transfer standard, designed to measure in percentage of reading the influence of frequencies, or AC/DC differences, between DC, 20 cps and 50 Kc/s on the indication of voltmeters, voltage calibrators and other transfer standards over a range of 1.5 v to 1125 v (lowest range of 0.5 v available on special order). Facilities are also provided for AC/DC current measurements by the direct connection of external thermoelements to an internal millivolt source or the employment of a special AC/DC transfer switch and current shunts. A *Sensitive Research* certificate is normally supplied (to accuracies of 0.02% of reading from 20 cps to 30 Kc/s and .05% of reading above 30 Kc/s to 50 Kc/s), but an NBS test report from 20 cps to 30 Kc/s (accuracy 0.01% of reading) and from 30 cps to 50 Kc/s (accuracy 0.02% of reading) is available when specified. 0.1% accuracy up to 1 megacycle below 15 v range. (Accuracy is based on present NBS capability. Model FLH was receiving NBS Certificates before this type of reporting was discontinued and accuracy is guaranteed to be within their stated uncertainty). Thermoelement has automatic overload protection.

LW

AC and DC Laboratory Standards

Model LW is a ±0.1% fs accurate, single phase, AC/DC electrodynamometer wattmeter. Application is primarily for the calibration of other wattmeters or the measurement of power from 25 to 6000 w fs. Shield design keeps phase angle errors at a minimum. For use down to 80% PF, on DC, 50 to 125 cps. 12″ vernier scale. Model L is similar to Model LW but measures from 30 to 1000 v or 50 ma to 20 amps AC/DC fs. Can be compensated for use up to 1000 cps. Maximum of 4 ranges on voltage or 2 on current. Model DYL is a ±0.01% accurate transformer coupled electrodynamometer with 15 fs ranges from 20 to 500 v and 10 ma to 10 amps AC, 50 to 70 cps.



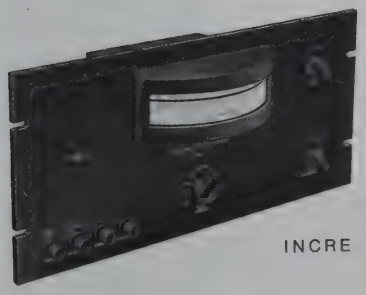


CHC

Model BS-1 is a ±0.05% accurate, *self checking,* volt-amp-milliammeter with 24 self contained, switch controlled ranges from 750 mv to 1500 v and 1.5 ma to 15 amps DC fs. References an internal standard cell. 300 mv range optional. Model B is similar but without *self checking* facilities. Up to 10 self contained ranges from 30 μa to 50 amps and 50 mv to 1000 v DC fs.

Heavy Current DC Ammeter

Model CHC is a portable self contained DC ammeter designed to simplify and speed up heavy current measurements. Range changing is by a single plug connector on the front panel. 6 overlapping full scale ranges are offered in a choice of two combinations as follows: 0 to 1/5/10/20/50/100. amps; 0 to 1.5/3/7.5/15/30 75 amps. Accuracy is ±0.2% fs. 6.3″ scale length.

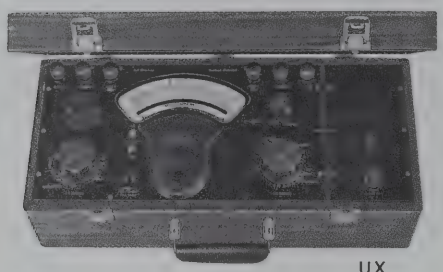


INCRE

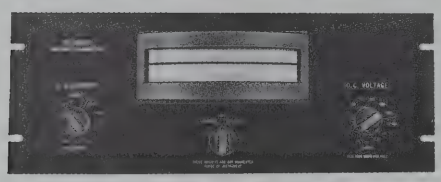
Expanded Scale Volt-Amp-Milliammeter

Model INCRE is a portable, ±0.05% accurate, expanded scale DC volt-amp-milliammeter featuring: (1) 10 full scale expansions per range, (2) an effective scale length of 63″, (3) an effective resolution of 1000 divisions (0.1% division that can be further interpolated to 0.01%), (4) precision of better than 0.01%. Ranges are 0 to 1/10/100/1000 ma; 1/10/100/1000 v (1000 ohms/v). Special instruments available from 100 mv to 2000 v and 100 μa to 30 amps. Available as a portable or edgewise panel instrument for standard 19″ rack mounting.

AC-DC POLYRANGER* INSTRUMENTS

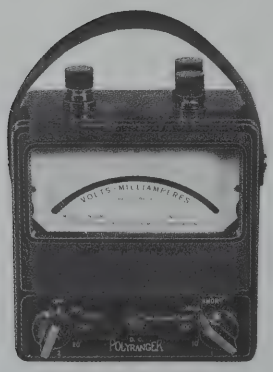


UX



Rack mounted *Polyranger* instrument

NPR (described on page S14)



University (described on page S14)

Polyranger* Instruments

The term *Polyranger* is the copyrighted Singer trademark for any portable AC, DC, or AC/DC multirange electrical indicating instrument for measuring both currents and voltages. The design of a *Polyranger* instrument offers the user four main advantages (1) versatility (2) a deluxe indicator with a very low cost per full scale range (3) overlapping ranges which enable most measurements to be made at, or near full scale for maximum accuracy and (4) AC and AC/DC types have true rms response.

Polyranger instruments are offered as permanent magnet, moving coil instruments for use on DC, transformer-coupled moving irons and electrodynamometers for measuring AC at standard power frequencies, and thermocouple instruments for AC/DC applications necessitating a relatively flat frequency response up to 15 Kc/s. Thermocouple instruments use a permanent magnet, double pivoted moving coil as their basic indicator.

Polyranger instrument designs combine reliable electromechanical indicators and newer electronic components that enable such features as *self checking,* automatic temperature compensation, overload protection and scale expansion. Accuracies are as high as ±0.25% fs. All *Polyranger* instruments have diamond pivots and sapphire spring mounted jewels to give a virtually friction-free moving element that will withstand the severest operating conditions. Vertically mounted models can be supplied in a 19″ x 7″ x 5/16″ rack panel to the same performance specifications as portable models. The basic indicator is housed in an edgewise panel case.

Thermocouple Polyranger* Instruments

Sensitive Research thermocouples have excellent AC/DC transfer characteristics (low reversal). Consequently, the accuracy specification of the thermal side of a *Polyranger* instrument is the same for both AC and DC. They can be calibrated directly on DC and only their AC/DC difference, or frequency influence, has to be checked by AC transfer methods.

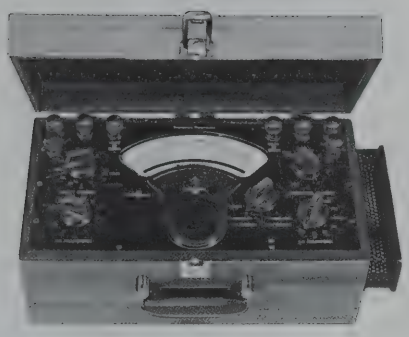
Models UX, U88, USP, and U-SP have two measuring circuits; one, for AC/DC use, includes the thermocouple, the other, for DC use only, bypasses the thermocouple. Because the primary application of a thermocouple is for AC measurements, the AC/DC circuit is referred to herein as the "AC side."

A thermocouple replacement feature (TRF), Type 357 or 362, allows for the field replacement of overloaded thermocouples with the retention of full instrument accuracy. Type 357 replacement thermocouples are furnished with two calibrated fixed resistors which must be soldered into place by the user; Type 362 thermocouples are furnished with a variable sensitivity resistor (to adjust full scale deflection of the instrument for maximum scale linearity) and replacement is by "plug-in."

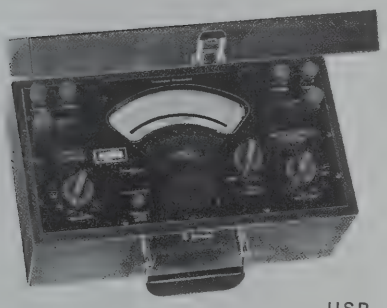
"Self Checking" AC and DC Volt-Ammeter

Model UX is a 51 range, AC/DC electrical indicating instrument featuring an expanded scale, automatic overload protection and autocalibration capability. Accuracy is ±0.5% fs from DC, 7 cps to 15 Kc/s. Switch controlled fs ranges are offered from 5 mv to 1000 v (5000 ohms/v) and 200 μa to 5 amps DC; 0.5 v to 1000 v (100 ohms/v) and 10 ma to 5 amps AC. 5.2″ scale length. *Self checking* system allows for full scale sensitivity calibration against a ±0.1% accurate, internal Zener diode reference source guaranteed stable to ±0.05% for 1 year. Thermoelement is protected for 500% overloads.

Continued on next page



U88



USP

A

DYP

Continued from previous page

"Self Checking" AC and DC Volt-Ammeter

AC scale resolution is increased by electrically suppressing initial 40% of full scale range; measurement capability is not affected since suppression occurs in lower areas where accurate readings cannot be obtained and all ranges are overlapping. Input 95 to 135 v, 60 cps (200 and/or 50 cps on special order).

Type 362 Thermocouple Replacement Feature is particularly valuable when installed in the Model UX since its circuit includes a variable resistance for the adjustment of the sensitivity of the thermocouple. By employing the instrument's self checking facility, the output of the thermocouple at full scale deflection can be set for maximum accuracy without using either an external source or standard.

88 Range AC and DC Volt-Ammeter

Model U88 is an AC/DC electrical indicating instrument with 88 switch controlled ranges, each overlapping so that all readings can be taken on the upper third of the scale. Accuracy is ±0.5% fs on DC and ±0.75% full scale on AC. Ranges fs from 200 μa to 1.5 amps and 20 mv to 750 v DC (3333 or 5000 ohms/v according to range); 10 ma to 3 amps and 0.5 to 750 v AC (66.6 or 100 ohms/v according to range). Frequency span is 7 cps to 5 Kc/s on voltage and 7 cps to 15 Kc/s on current. 5.2″ scale length.

Universal AC and DC Volt-Ammeter

Model USP is an AC/DC electrical indicating instrument with 28 overlapping ranges. It has the advantage of being more economically priced than the Models UX and U88 while still maintaining the versatility of these instruments by covering the same broad measuring range and incorporating some of their most desirable features. Switch controlled full scale ranges from 200 μa to 2 amps and 5 mv to 1000 v DC (5000 ohms/v on 5 and 50 mv, all other ranges 1000 ohms/v); 15 ma to 3 amps and 0.3 to 750 v (100 ohms/v). 5.2″ scale length. Model U-SP is similar to USP but has added DC ranges of 2/20 amps and 4/40 v; AC ranges from 10 ma to 3 amps and 0.3 to 1000 v. Accuracy ±0.75% AC and ±0.5% DC of full scale.

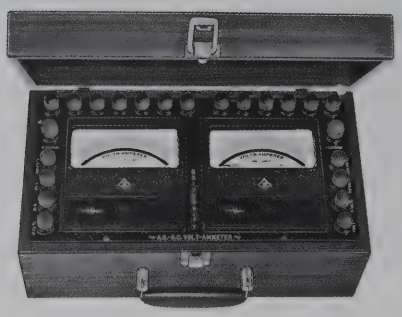
AC/DC Volt-Ammeters

Model A *Polyranger* instruments are ±0.75% accurate, switch controlled AC/DC electrical indicating instruments designed primarily for the measurement of AC over a wide range of audio frequencies. They differ from other AC/DC *Polyranger* models in that they are smaller sized (but have a longer scale, 6.3″) and have one pair of input terminals and a single circuit for both AC and DC measurements. Available in six fs range combs. as follows: 1-AA, 10 ma to 1 amp and 0.5 to 500 v (12 ranges); 1-AB, same as 1-AA except add 5 amps range; 1-AC, same as 1-AA except add 1000 v range; same as 1-AC except add 5 amps and 1000 v range (all combs. 100 ohms/v); 2-A, 2 ma to 1 amp and 2 to 500 v (11 ranges; only *Polyranger* instrument with a sensitivity of 500 ohms/v); 3-A, 15 ma to 5 amp and 0.5 to 1500 v (14 ranges; 100 ohm/v).

AC Dynamometer Volt-Ammeter

Model DYP is a ±0.3% accurate, switch controlled, transformer coupled dynamometer for 60 cps measurements only (50 cps on special order). Comb. #1 has 12 fs ranges, 10 ma to 10 amps and 10 to 1000 v; Comb. #2 has 20 fs ranges, 5 ma to 10 amps and 5 to 1000 v (2000 v optional). 6.3″ scale length.

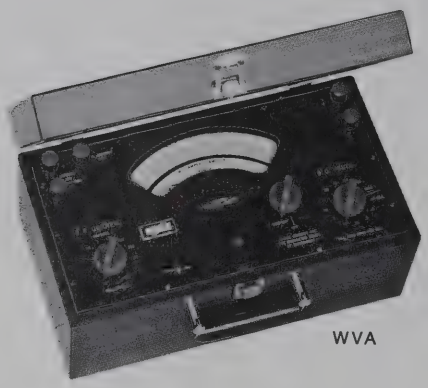
AC-DC POLYRANGER* AND GENERAL PURPOSE



UVA

AC and DC University Volt-Ammeter

Model UVA is a 22 range AC and DC *Polyranger* instrument consisting of two separate University Model electrical indicating instruments mounted in a single case. Offered as a versatile, low cost, rugged indicator that has wide application in educational institutions and industrial field testing. Designed for use by relatively inexperienced personnel. All ranges engraved on separate binding posts, minimizing the danger of connecting incorrectly into a circuit or of inadvertently selecting the wrong range by a switch. Both indicators withstand overloads of 500% without additional protection (100% on 1000 v range). AC instrument is ±0.75% accurate transformer coupled moving iron; DC is ±0.5% accurate permanent magnet moving coil. Ranges from 1 ma to 10 amps and 50 mv to 1000 v DC (1000 ohms/v); 10 ma to 10 amps and 10 to 500 v (1 to 5 va burden). 4″ scale lengths.

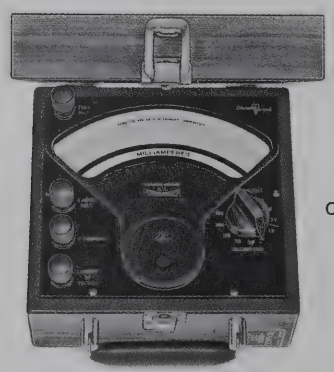


WVA

DC Reference Standard Volt-Ammeters

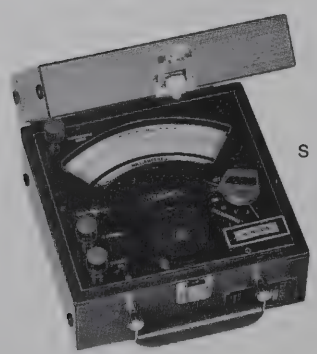
Model WVA offers the widest measuring capability available in a self-contained ±0.25% accurate DC reference standard indicating instrument. Its 27 overlapping ranges from 1 ma to 15 amps and 100 mv to 1000 v (1000 Ω/v), enable readings to be taken at, or near full scale. Voltage and current circuits are independent of each other and "dummy loaded." When current and voltage are supplied at the same time, by reversing the circuit selector switch, almost simultaneous readings can be taken without unbalancing either input, and values of DC resistance and power can be calculated. Instrument contains a 0-1 scale which indicates current being drawn during voltage measurements. 6.3″ scale length. Switch controlled. Excellent stability and ruggedness. 1 second response time.

The Model C is a 14 range ±0.25% accurate DC reference standard indicating instrument similar in concept to the Model WVA but smaller in size and more economically priced. Offered in three range combs. as follows: 1-C, from 1 ma to 3 amps and 3 to 1000 v; 3-C, from 1.5 ma to 3 amps and 3 to 1500 v; 4-C, 10 ma to 10 amps and 1 to 1000 v. Sensitivity 1000 ohms/v. 6.3″ scale length.



C

Model S *Polyranger* instruments are 13 range, switch controlled, high sensitivity DC reference standards designed to measure over a broad range of currents and voltages with measurement circuit loading. Accuracy is ±0.5% fs. Available in three fs range combs. as follows: 1-S, 100 μa to 1 amp and 5 mv to 1000 v (1000 ohms/volt except 5/10 mv 5000 ohms/v); 2-S, 200 μa to 2 amps and 5 mv to 200 v (5000 ohms/v); 3-S, same ranges as comb. 1-S except all ranges 10,000 ohms/v. 5.2″ scale length. RF measurements can be made via external thermoelements connected to the 5 and 10 mv ranges.



S

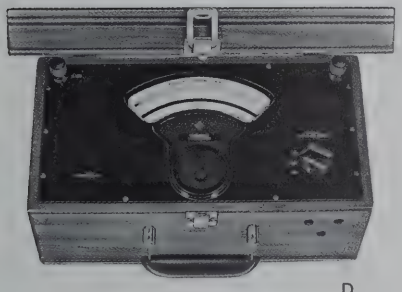
Low Cost DC Volt-Ammeter

Model NPR is a compact ±0.5% accurate, switch controlled general purpose indicating instrument available in three range combs. as follows: 1-NPR, 200 μa to 2 amps and 2 v to 500 v (9 ranges); 2-NPR, 1 ma to 500 ma and 5 to 500 v (10 ranges); 3-NPR, 5 ma to 1 amp and 5 to 500 v (11 ranges). Sensitivity 1000 ohms/v. 6.1″ scale length. (Photo on page S12.)

University Model is a 9 range, ±0.5% accurate smaller sized, high sensitivity instrument. Available in two range combs. as follows: 1-UD, 100 μa to 1 amp and 2 to 500 v; 2-VO, 200 μa to 2 amps and 2 to 500 v. Sensitivity 1000 ohms/v. 4″ scale length. (Photo on page S12.)

C

University



D

9201

DC Reference Standards

Model C is a rugged ±0.25% fs accurate permanent magnet moving coil electrical indicating instrument. Moving element features an exceptionally high torque to weight ratio. 6.3″ scale length. Up to 9 self contained ranges available in switch controlled multirange combs. from 50 μv and 50 mv DC fs. Millivoltmeter available calibrated for use with external heavy current shunts. Sensitivities to 20,000 ohms/v. Design emphasis is on stability and sturdiness for long term accuracy and reliability.

Model S is a deluxe high sensitivity ±0.5% fs accurate instrument of the same superb quality and physical dimensions as the Model C. Up to 9 switch controlled ranges in various combs. available from 1.5 μa and 1 mv fs. Sensitivities to 500,000 ohms/v (1,000,000 ohms/v when zero center). Constant resistance multirange microammeters available for special applications. Low range millivoltmeters are particularly suited for use with thermal converters for ultra high frequency AC measurements. Model HS is an ultra high sensitivity multirange millivoltmeter designed mainly for use in corrosion and electrolysis measurements. Model J is a ±0.5% accurate instrument made primarily to use as a bench mounted, pointer type, high sensitivity galvanometer.

Model N is a low cost permanent magnet moving coil instrument with many features of higher priced indicators. Accuracy is ±0.5% or ±0.25% fs as required. Housed in a rugged plastic case for field use. Up to 5 switch controlled ranges available from 50 μa and 50μv (up to 50 amps self contained). Sensitivities to 5000 ohms/v. 6.1″ scale length.

University Model is a low cost, compact, ±0.5% accurate version of the Model S, having slightly less sensitivity and resolution. Up to 5 switch controlled, self contained ranges from 2 μa and 2 mv fs. Sensitivities to 5000 ohms/v. 4″ scale length. Model UTS is a portable DC test set with 4 University Model indicating instruments to measure from 50 μa to 60 amps and 20 mv to 1200 v. Contains a Wheatstone Bridge, a decade resistance box and all necessary switching and facilities to make potentiometer voltmeter, zero resistance, DC power and high resistance voltmeter measurements.

AC and AC/DC Reference Standards

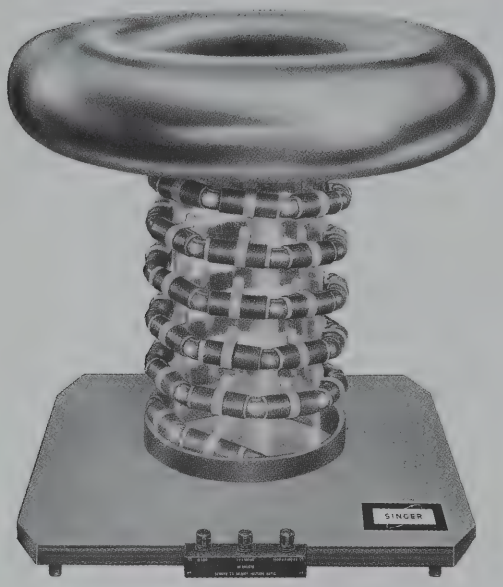
Model D is a rugged AC/DC ±0.25% fs accurate dynamometer electrical indicating instrument. 6.3″ scale length. Up to 4 self contained ranges available in switch controlled multirange combs. from 1.5 to 1000 v and 5 ma to 20 amps. Frequency response DC, 25 to 2500 cps.

Model MI is a rugged ±0.5% fs accurate moving iron electrical indicating instrument. Up to 3 self contained ranges available from 10 ma to 20 amps and 7.5 to 750 v. Frequency response 25 to 500 cps. 6.3″ scale length. Special transformer coupled voltmeter has 8 switch controlled ranges from 3 to 750 v fs. Model NSI is a low cost ±0.5% fs accurate version of the Model MI. Housed in a molded plastic field case. 6″ scale length. University Model is a compact low cost ±0.5% fs accurate version of the Model D. Up to 4 ranges available from 10 ma to 1 amps and 30 to 750 v. Frequency response DC, 25 to 125 cps (500 cps on special order). 4″ scale length.

Test Instruments

Model 9101 is a ±2% accurate electronic voltmeter with 12 fs ranges from 1 mv to 300 v and wide frequency response from 10 cps to 4 Mc/s. −60 to +50 dbm scale. For use as video amplifier with up to 150 gain. Model 9201 is an electronic volt-ohmmeter with 6 fs ranges from 0 to 300 v AC and 7 fs ranges each from 0 to 1000 v DC, and 0 to 500 megohms. Accuracy is ±3% at fs.

HIGH VOLTAGE MEASUREMENT AND



PARK

High Voltage Divider

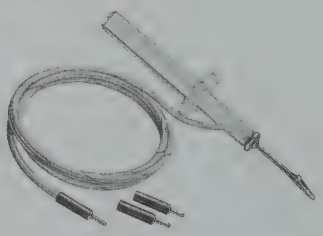
Model PARK Voltage Divider is constructed to a design by J. H. Park. (Ref: "Journal of Research" of National Bureau of Standards, Engineering and Instrumentation Vol. 66C, No. 1, Jan. — Mar., 1962. Reprints available upon request.) It is similar to the NBS standard employed in their calibration of high voltage instruments. Each 100 kv divider consists of 100 individually shielded one-megohm resistors, matched to each other to achieve an approximate temperature coefficient of less than 1 ppm/°C, and connected in series to form a vertical helix between a ground plate and a high voltage electrode. Uniquely shielded, testing indicates that corona, heating and leakage errors are less than 10 ppm at 50 kv and 50 ppm at 100 kv.

The divider's special "hat" is designed to give uniform gradients from the high voltage electrode to ground and allows stacking of additional 100 kv units for higher voltage measurements. Each unit is only 22¼″ high! DC Ratio Accuracy: ±.05%, 100 kv to 1 v; ±.5%, 100 kv to 1 kv. AC Ratio Accuracy: ±.5%, 50 kv (max.) to 500 v. (60 cps only). Recommended readout instrument at 1 v output tap is a precision DC potentiometer, at 1 kv tap (.5 kv on AC) recommended instrument is a ±.5% accurate electrostatic voltmeter (*Sensitive Research* Model ESD described on next page).

DCHI

DC Kilovoltmeter (multirange)

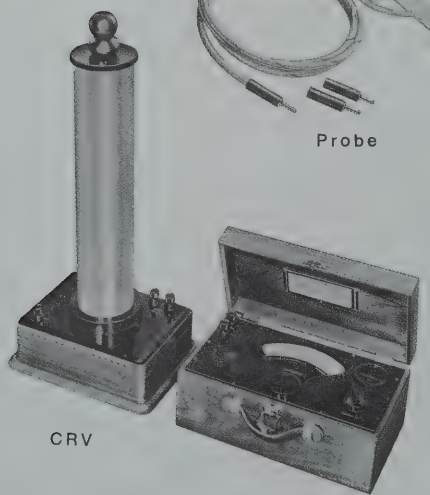
Model DCHI is a multirange permanent magnet moving coil, DC kilovoltmeter. Available at 50,000 ohms/v, ±1% fs accuracy, ranges of 1.5/3/7.5/15 kv or 3/7.5/15/30 kv, and at 75,000 ohms/v, ±.5% fs accuracy, ranges of 2/5/10/20 kv. The indicator is a University Model ±.5% accurate microammeter with a 4″ scale length. It is self-contained in a moulded bakelite case and internally bracketed to the instrument panel. Size: 13¾″ x 7½″ x 8″ h.



Probe

High Voltage Probe

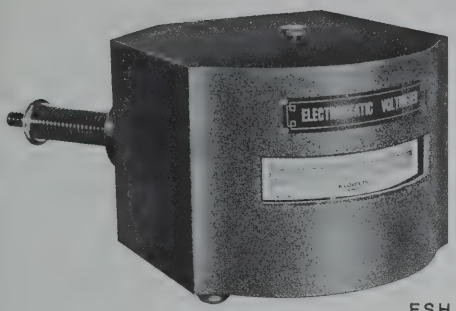
For operator safety when making high voltage measurements an insulated probe is available and recommended for use with the Model DCHI. The probe has a polystyrene handle with a special hand guard, and an anti-corona ring at its tip. Its flexible test lead is a shielded high voltage cable. A clip attachment is provided.



CRV

Electrostatic Peak — RMS Voltmeter

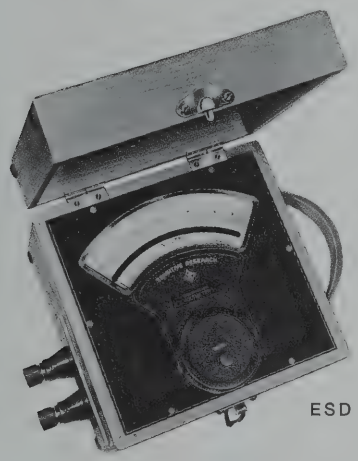
Model CRV is an electrostatic peak (or crest) voltmeter for measuring either AC or pulsed DC sources of 20 pulses/sec. or more. 10,000 megohms input impedance; 25 mmfd for rms measurements, 15 mmfd for peak measurements. Contains a peak voltage rectifier circuit and switching to allow measurement of either positive or negative peaks, or true RMS values. Basic electrostatic instrument range is from 0 to 1 kv. External multipliers are available up to 100 kv. ±1% fs accuracy. 5.2″ scale length.



ESH

Electrostatic Voltmeter (high voltage)

Model ESH AC/DC electrostatic voltmeter is available as a single range instrument up to 100 kv fs (140 kv DC only), or with as many as 4 switch-controlled ranges from 5 to 50 kv fs. DC input resistances to 5 x 10^{15} ohms. Capacitance varies from approx. 30 mmfd on 5 kv range to 10 mmfd on 50-100 kv ranges. Reads true RMS. Accuracy is ±1% fs (±.5% up to 30 kv on special order). 6″ scale length. Transit lock and brackets for panel mounting available. Maximum frequency usage is expressed as follows: $f = 2\pi fCE$, where f = max. allowable operating frequency, C = capacitance of instrument in farads, E = voltage in volts.



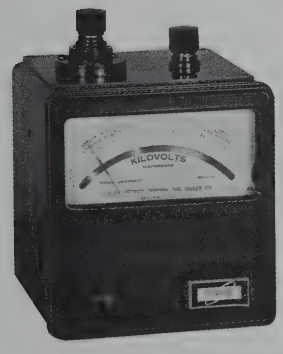
ESD

Electrostatic Voltmeter (portable)

Model ESD portable AC/DC electrostatic voltmeter is available as a single or multirange instrument to measure from 120 to 6 kv fs. Insulation resistance is 1 x 10^{15} ohms. Capacitance varies from approx. 225 mmfd for a 120 v range to 20 mmfd for a 6 kv range. Multirange instruments are designed for AC/DC measurements on first range, AC only on higher ranges. ±.5% to 1% fs accuracy (±1.5% for ranges of 150 v and less). 5.2″ scale length. Size: 7¾″ x 7½″ x 6⅛″. Available as edgewise panel instrument with the same performance characteristics except insulation resistance approx. 1 x 10^{13} ohms.

Electrostatic Voltmeter (small portable)

University Model is a smaller, more economical version of the portable Model ESD. Single and multirange instruments available from 300 v to 5 kv fs. ±1% fs accuracy. 4″ scale length. Moulded bakelite case. Size 5¼″ x 5″ x 4⅜″.



University

Electrostatic Voltmeter (expanded scale)

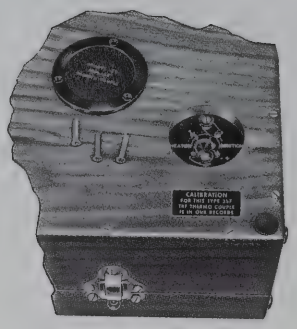
Model ESX is an AC/DC, 0 to 150 v fs, true rms responding electrostatic voltmeter with an adjustable built-in 150 v battery power supply. Scale expansion is achieved by self powering a full scale deflection and bucking out the internal supply with an external input. The approximately square law scale is read in reverse and scale expansion is greatest in the area of 0 to 75 v. Deflection automatically reverses up scale again on the application of more than 150 v to produce an additional 150 v to 300 v DC range. Accuracy is ±1.5% fs. Input resistance is 1 x 10^{14} ohms minimum. Substantially zero current drain allows usage for such applications as the measurement of nuclear batteries and similar equipment. AC operation is the same as standard 0 to 150 v instrument. Frequency range is from DC and 25 cps to .75 Mc/s.

VPA

Electrostatic Peak Voltage Adaptor

Model VPA is used with electrostatic voltmeters. Available with maximum inverse peak voltage ratings of 3 kv (5 microseconds changing time) and 30 kv (10 microseconds changing time). Discharging time 10 microseconds. Can be supplied to measure negative or positive peaks. Battery operated. Frequency range 60 cps to 1 Mc/s.

THERMOCOUPLE METERS

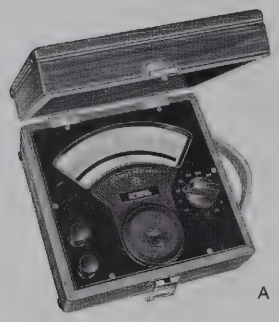


TRF
(Thermocouple Replacement Feature)

Thermocouple instruments offer the user significant advantages in frequency response and sensitivity over other AC types with true rms response. They can be used on DC and AC from 7 cps to 20 Mc/s, and in instances where UHF thermal converters are employed, this frequency range can be extended to over 100 Mc/s. *Sensitive Research* thermoelements have excellent AC/DC transfer characteristics (low reversal). Thermocouple instruments can be calibrated directly on DC and only their AC/DC difference, or frequency influence, has to be checked by AC transfer methods. A thermocouple field replacement feature (TRF) is supplied in the Models A and AU. Automatic or manual "Push to Read" overload protection is available. Automatic temperature compensation from 20° to 30° C is standard (except University Model).

Audio Frequency Volt and Milliammeters

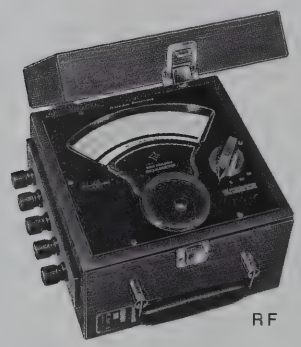
Model A series consists of AC/DC multirange milliammeters and single or multirange voltmeters. Accuracy is ±0.5% fs (±0.75% for instruments with fs ranges of 3 ma or less or a sensitivity of 500 ohms/v). Multirange combinations are offered from 1 ma to 1.5 amps; 0.2 v to 1.5 kv. Frequency range is 7 cps to 7 Kc/s on voltage and 7 cps to 15 Kc/s on current. Sensitivity is 100, 200 or 500 ohms/v. 6.3″ scale length. (Single range milliammeters have a frequency response up to 1 Mc/s and are listed under Model RF.) Model AU is identical to the Model A, except frequency range is extended to 35 Kc/s on voltage and 20 Kc/s on current.



A

Radio Frequency Volt, Amp and Milliammeters

Model RF series consists of AC/DC single range and multirange instruments for use up to 20 Mc/s. Model RF multirange voltmeters utilize special switching to increase frequency range considerably beyond normal limits of other instruments containing this operational feature. Frequency influence is negligible over the first 20% of their frequency span. Accuracy is ±0.5% fs + (±0.5% max. frequency influence) on multirange units from 1 v (5 Mc/s) to 300 v (150 Kc/s). Instruments with a single range of 1 v or 3 v have a ±0.5% frequency response to 10 Mc/s. RF ammeters and milliammeters are available with accuracies of ±1% fs from 1 ma to 100 amps. 6.3″ scale length.



RF

Compact Thermocouple Instruments

University Model comprises a series of ±0.75% accurate, low cost, small sized milliammeters and voltmeters for AC/DC measurements up to 7.5 Kc/s (single range milliammeters up to 500 Kc/s). Multirange instruments are switch controlled. Up to 7 fs ranges available from 2 ma to 1 amp or 200 mv to 300 v (100 or 500 ohms/v). 4″ scale length. University Model is comparable in general construction quality to Model A, but has certain limitations in range, frequency response, resolution and the accessory features it can contain (temperature compensation, TRF, etc.), because of relatively small size.

University

DC Millivoltmeter and External Thermoelement

Radio frequency measurements up to 1000 Mc/s can be accurately made with a precision DC millivoltmeter (accuracy ±0.5% fs) and external thermal converters such as the Model T, TX, ATV and CTC described on page S3. Suggested millivoltmeter is Model S with ranges of 0-2/5/10 mv at 5 ohms/mv (add 1 mv range for ATV). The scale of the indicating instrument is drawn directly in millivolts and the characteristics of individual thermoelements are plotted against it to obtain a calibration curve in AC voltage or current.

AC/DC WATTMETERS

SINGER
METRICS DIVISION

Sensitive Research* INSTRUMENTS
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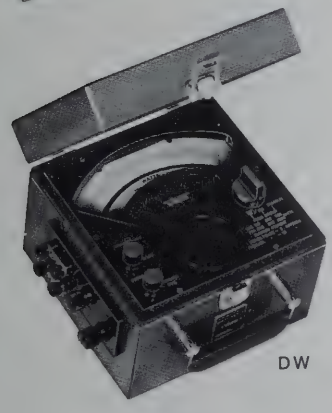
PDW

VAW



DW

University

Polyphase Wattmeters

Model PDW is a multirange 2 element AC/DC electrodynamometer wattmeter for the measurement of single and 3 phase power down to 50% PF and up to 800 cps. Can be used in 3 phase 3 wire circuits, single phase 3 wire circuits and 3 phase 4 wire circuits. Indicates 3 phase power for any combination of balanced or unbalanced loads. Accuracy ±0.5% fs. 6.3″ scale length. Model PDLW is a ±0.75% accurate wattmeter for use down to 20% PF and up to 500 cps. 5.2″ scale length. Compensating inductor available for third leg of 3 phase circuits to balance load imposed by wattmeter insertion.

Volt-Amp-Wattmeter

Model VAW, volt-amp-wattmeters, are transformer-coupled electrodynamometers that make 50 to 125 cps or 50 to 800 cps tare-free compensated measurements of AC power down to 50% PF in 12 ranges from 12.5 w to 5 kw fs. Has potential drop ranges of 25/50/100/200/500 v fs; current ranges of 0.5/1/5/10 amps fs (12.5/25 w and 25/50 v included in 50 to 125 cps model only). Accuracy on current and voltage ranges ±0.5% fs; on watts ±0.75% fs. Switch controlled ranges. Measures all circuit parameters without necessity of changing external connections. Special 10 ma range for current measurements only. 5.2″ scale length. Self-contained in portable case.

Single Phase Wattmeters

Model DW is a ±0.25% accurate single phase AC/DC electrodynamometer wattmeter for use down to 50% PF and frequencies of 25 to 800 cps (2500 cps on special order). Overall accuracy, ruggedness and stability make it ideally suited for use as either a calibration standard or general purpose testing instrument. 6.3″ scale length. Y Boxes available for measurements of balanced 3 phase power. Model DLW is a single phase ±0.5% accurate wattmeter for use down to 20% PF and up to 500 cps. University Model, having accuracies of ± 0.5% fs down to 50% PF and ±0.75% down to 20% PF, is a compact version of the Models DW and DLW. Has the advantage of being more economically priced than these instruments while covering essentially the same wide measuring range. Molded bakelike case. 4″ scale length.

Special Wattmeters

Special low voltage wattmeters are available for measurements down to 50 mw fs. A 10 range switch controlled University wattmeter is available with fs ranges of 12.5/25/50/100/200v, 2/4 amps maximum current at 10% PF and 2.5 to 80 w. Frequency range is 50 to 1000 cps.

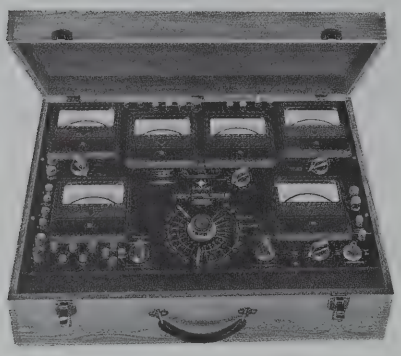
Power Factor Meters

Model PF is a single phase electrodynamometer power factor meter accurate to ±0.005 PF. Ranges are 0.5 — 1 — 0.5 PF lead to lag; 60 and/or 400 cps; 115 and/or 230 v; 2.5/5 or 5/10 amps. 6.3″ scale length. Model PPF is a 3 phase power factor meter for balanced loads only. General specifications same as for Model PF except frequency range 50 to 500 cps.

AC Test Sets

Models U60 AC (50 to 60 cps) U400 AC (50 to 400 cps) and U1000 AC (50 to 1000 cps) have a separate University model wattmeter (2) voltmeter and ammeter, with fs ranges of 5 to 2000 w, 30 to 300 v and 0.01 to 10 amps. For use down to 10% PF. Portable and self-contained.

MAGNETIC TESTING AND SPECIAL PURPOSE

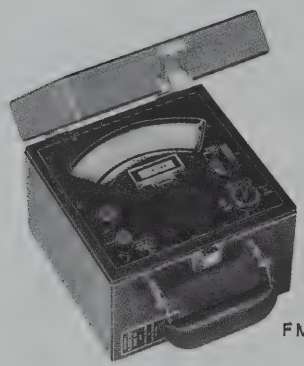


MAT

Universal Magnetic Testing Set

Model MAT performs magnetic measurements in accordance with ASTM specifications listed in A343. Applications are for core loss measurements (utilizing Model EPS 25 cms Epstein Frame or E and I cores), determination of DC hysteresis loops, measurements of total flux of hard magnets and magnet field strength, and AC permeability testing (with accessory Model MU mutual inductors). Test set compensated for internal power losses and core loss is read directly in watts without correction. Switch controlled instrumentation consists of a ±0.5% accurate DC ammeter with 10 fs ranges from 30 ma to 30 amps, a ±0.75% accurate overload protected AC/DC rms ammeter and voltmeter with 7 fs ranges from 50 ma to 5 amps and 5 fs ranges from 15 to 300 v (500 ohms/v) respectively; a ±0.5% accurate AC average reading flux voltmeter with 5 fs ranges from 15 to 300 v (333 ohms/v); a ±0.75% accurate AC/DC single phase (20% PF) wattmeter with ranges of 12.5/25/50/100 200 v and 0.2/0.4 amps (normal), 2/4 amps (max.); a ±1% accurate DC fluxmeter with 5 ranges from 500,000 to 50,000,000 maxwells (sensitivity 10,000 lines/div. using a 1 turn search coil). 4″ scale lengths. Compensated up to 500 cps.

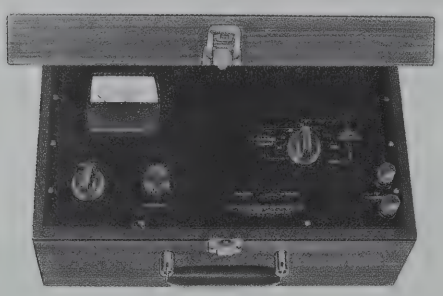
Model COL is a production type magnetic test set designed specifically for AC measurements of core loss, excitation currents and permeability. It has the same AC measuring ranges but differs from the Model MAT in that it provides faster, easier operation at higher accuracy in these areas. Whereas each indicating instrument in the Model MAT can be used separately, the instruments in the Model COL are connected internally and can only be employed as a fixed combination. 6.3″ scale length.



FM

DC Fluxmeters

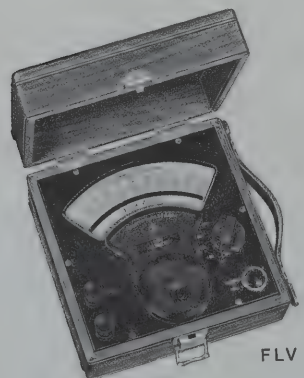
Models FM (multirange) and FS (single range) are ±1% accurate direct reading DC fluxmeters for the measurement of total magnetic flux in cgs lines, and use in related applications such as obtaining B-H curves and DC permeability testing. If area of search coil is known, readings can be converted to gauss. Model FM has 5 switch controlled ranges from 500,000 to 50,000,000 lines fs. Sensitivity is 1000 lines/div. using Model GPS, a 15 ohm 10 turn search coil with a 15 cms mean area and 1¼″ center hole. Operation is independent of probe insertion speed. 5.2″ scale length.



FC

Fluxmeter Calibrator

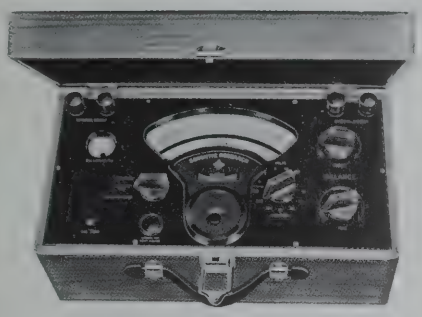
Model FC is a fluxmeter calibrator that provides ±0.2% accurate calibration points from 100,000 to 50,000,000 flux linkages, for checking Model FM and FS fluxmeters, or any other fluxmeter or ballistic galvanometer designed for use with a 15 ohm external circuit. Model FCM is a 0.5% accurate standard 50,000 line magnet and special search coil for one point calibrations.



FLV

Average Reading Flux Voltmeters

Models FLV (±0.5% accurate) and FLVC (±0.25% accurate) are full wave rectified average reading AC voltmeters calibrated in terms of the rms values of a sine wave. Designation as "flux voltmeters" arises from applications in magnetic measurements to determine the max. flux density (Beta) of transformer windings. Flux density in a magnetic core is proportional to the average value of the positive and negative half values of voltage. Near saturation flux density reading errors result in still larger core loss and exciting va errors. As many as 4 fs ranges available in various combs. from 5 to 300 v at 3333 or 1000 ohms/v, compensated from 25 to 1000 cps. 6.3″ scale length.



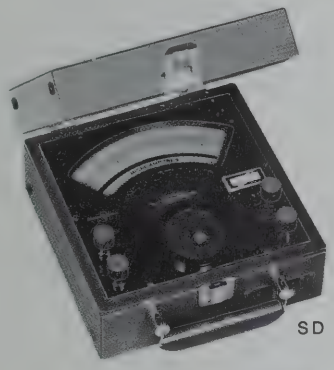
PV

Potentiometer Voltmeter

Model PV is a switch controlled DC potentiometer voltmeter with infinite resistance at null or a direct reading DC voltmeter with sensitivity of 5000 ohms/v. Application is for corrosion, electrolysis and thermocouple measurements, or in any other circuit where excessive current drain cannot be tolerated. ±0.35% fs accuracy. Multirange from 2 mv to 20 v fs. 5.2″ scale length. Galvanometer detects 1 v through 10 megohms. Battery operated.

Zero Resistance Current Meter

Model ZR is a ±0.5% accurate zero resistance microammeter-milliammeter that measures with zero volt loss. Application is for corrosion, electrolysis, photocell and electrolytic cell measurements. Multirange switch controlled combinations from 10 μa to 300 ma. 5.2″ scale length. Battery operated.



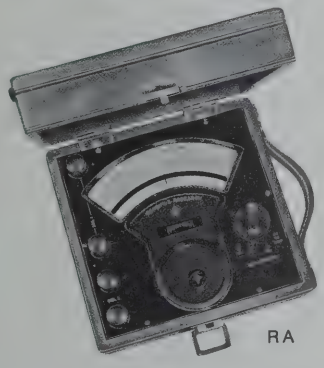
SD

Differential Instruments

Model SD measures the difference between two DC currents or voltages. Inputs are isolated. Accuracy is ±0.5% fs for most ranges between 2 μa to 500 ma. Normally furnished zero center. Uniqueness is ability to withstand sustained overloads of 1000% which results in a 10X increase in comparison accuracy and scale resolution. 5.2″ scale length. Model JD is a differential galvanometer with a 3.25″ scale length that permits higher sensitivity. Suitable for horizontal bench mounting. Model JDJW-4 A is an edgewise panel instrument with a 4″ scale length.

Current Product Instrument

Model DYSP is a ±0.25% accurate electrodynamometer that has separate stationary field and moving coil circuits for independent current inputs. Reads the product of these inputs. Frequency range is DC, 25 to 500 cps, or any single frequency between 25 and 2000 cps. 6.3″ scale length.



RA

Frequency Meter

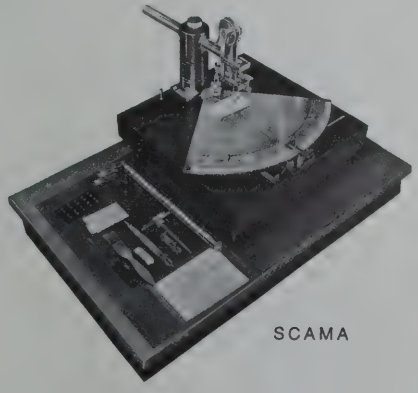
Model FRE is a ±0.25% accurate, expanded scale (±10% of center frequency) or conventional zero left indicating instrument for measurements in the low audio frequency range. 6.3″ scale length.

Ratiometer

Model RA divides or measures the ratio of two DC inputs. Accuracy is ±0.25% when operated at maximum rated input. 50 μa minimum current. Range is from zero to infinity. Expanded scales available. 6.3″ scale length.

Form Factor Test Set

Model E indicates the deviation from true rms of average or peak reading instruments when used on non-sinusoidal wave forms and gives a correction factor in terms of rms. Range ratios 1.0 to 1.7 — peak to rms; infinity to 1 — rms to average. Measures from 0 to 500 v up to 500 cps.



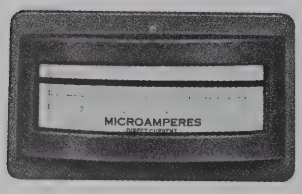
SCAMA

Scale Drawing Machine

Model SCAMA is a manually operated drafting machine for precision drawing and printing of electrical indicating instrument scales. Essential equipment for all service stations. Identical to machine used to draw *Sensitive Research* scales. Draws scales of other manufacturer's instruments. Accommodates all flat scale plates from instruments with an angular deflection of 110° or less. Special adaptor for circular scale instruments with angular deflection up to 360°. Furnished with all accessories.

EW-7A

Rack mounted *Polyranger* instrument



JW-4A

NP

Sensitive Research AC and DC panel instruments are precision portables adapted for panel mounting. They are available as flat faced rectangular and curved scale edgewise types. With minor variations, construction is identical to their counterpart bench models, and in the case of edgewise panel instruments this also applies to critical performance characteristics. Data cards are furnished listing temperature corrections and maximum overload ratings. In general all panel instruments conform to ASAC-39.1 and MIL-M-16034B, where applicable. Special scales, pointers and calibrations are standard practice and, depending on complexity of individual requirements, are supplied at little or no extra charge. Magnetic shielding is well within ASA specifications but if desired, for maximum accuracy, a complete panel of instruments can be calibrated together in their intended operating positions. All models (except the JW) with ranges switched controlled.

AC - DC Edgewise Panel Instruments

All *Sensitive Research* precision portable instruments (with the exception of Models N, J and University) can be furnished in the Type EW-5A (5″ scale length) and EW-7A (7″ scale length) edgewise aluminum cases for vertical panel mounting. *Polyranger* models and other instruments, where the number of ranges or design demand more space, are furnished on a standard 19″ rack panel with the basic indicator in an EW case. A typical rack mounted *Polyranger* instrument is pictured.

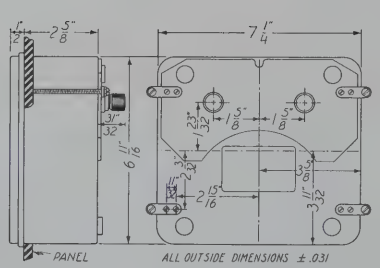
Mounting dimensions and construction details of the shallow EW-7A case are shown below. The EW-5A case differs in that it is $7\frac{1}{8}$″ wide. EW cases for the mounting of electrodynamometers differ in that they are $4\frac{3}{16}$″ deep. Any portable installed in an edgewise case derives its nomenclature by adding the case type number to the model letter (example: Model C in an EW-7A case becomes Model CEW-7A).

Model JW-4A is a ±0.5% accurate, low cost, compact edgewise panel instrument available with up to 3 self contained ranges from 2 μa and 2 mv. DC fs. (5000 ohms/v). Measures $5\frac{1}{4}$″ across and 3″ deep. 4″ scale length. Model JDJW-4A is a differential instrument in a JW-4A case. Model JWSP differs from JW-4A only in that its front panel is $7\frac{1}{2}$″ across to accommodate a selector switch and allow up to 5 self contained ranges.

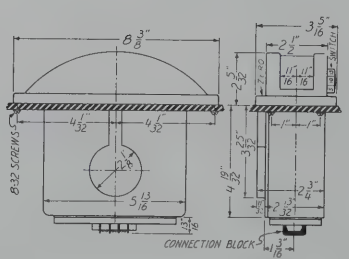
DC Rectangular Panel Instruments

Model NP is a ±0.5% accurate rectangular panel instrument with a 6.1″ scale length and up to 5 switch controlled ranges in various combs. from 200 μa and 50 mv fs. Sensitivities to 5000 ohms/v. Dimensions as shown below.

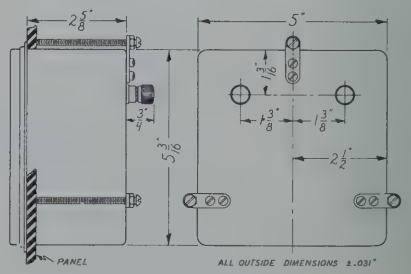
Model UPP is a ±0.5% accurate compact, lower cost panel instrument similar in performance to the Model NP. Current ranges start from 30 μa fs (1% accuracy up to 200 μa). 4″ scale length. Dimensions as shown below.



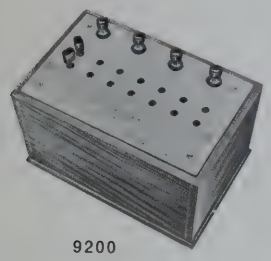
NP



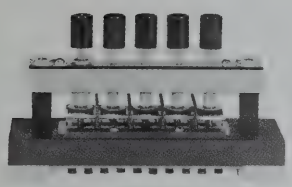
EW-7A



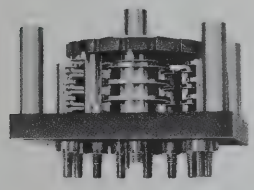
UPP



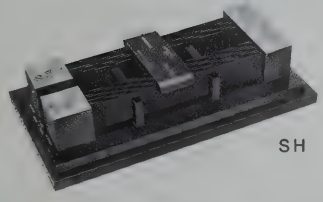
9200



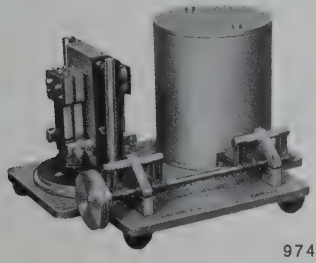
9145A (cover removed)



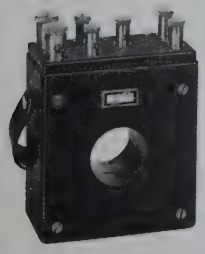
9600



SH



9744



TR

Standard Resistors

Standard resistors for high accuracy potentiometer measurements of current. Type 9200 allows plug selection of any one of 7 four terminal resistors from .01 to 10,000 ohms (100 mv potential drop). Accuracy .01%; stability 0.002%. Types 1659, 1682 and 3111 are .03% oil filled four terminal shunts for use from 0.03 to 200 amps at 10 to 200 w. Special shunts available from 0.0001 ohms.

Low Thermal Noise Switch

Type 9145A selector switch is a 5 pushbutton switch with max. noise level of 0.01 μv. Each self-wiping switch is break-before-make DPDT. Can be used as reversing switch. Tapping keys can be locked down.

Dual Contact Switches

Type 9630 self-wiping dual contact copper switches are available for transfer and/or reversing applications demanding the highest degree of precision. Generation of thermal emfs is as low as .01 μv. Available with as many as 25 positions, 4 poles and 3 brushes. Wiper assemblies can be paralleled for low resistance applications. Switch resistance as low as 100 microhms between soldering points with 10 microhms repeatability between contact points. Constructed to a patented design.

Type 9600 Reversing Switch is a constant resistance switch to simultaneously reverse the battery, standard cell and input emf of DC potentiometers while temporarily disconnecting the galvanometer.

Heavy Current Shunts

Model SH is a $\pm$0.1% accurate (0.05% on special order), 4 terminal, 50, 100 or 300 mv drop, laboratory standard, manganin shunt designed for continuous duty. Ratings available up to 1000 amps.

Low Thermal Noise Choppers

Types 9742, 9743, and 9744 are mechanical choppers whose noise level does not exceed 0.02 μv. They contain 2, 3 and 4 DPDT switches, with phase and make-break ratio individually adjustable. Chopping frequency up to 90 cps.

Current Transformers

Model TR, current transformers, (25 to 500 cps) extend the ranges of AC indicating instruments. Type 1 has a ratio accuracy of $\pm$0.25% and is mainly for use with ammeters having a burden lower than 5 va. Type 2 has a ratio accuracy of $\pm$.15%, lower phase angle errors, 15 va allowable loading, and is suitable for use with wattmeters or ammeters having a relatively high burden. Primary ranges are 10/20/50/100/200/400/800 to a 5 amp secondary.

Voltage Multiplier

Model MUL is $\pm$0.1% accurate (0.05% on special order) voltage multiplier to extend the range of a voltmeter or be placed in series with a microammeter or milliammeter to create voltage ranges. Multirange combinations available up to 10 kv at 10,000 ohms/v (up to 1 megohm/v on special order). See Model Park high voltage divider on page S16.

Unsaturated Miniature Standard Cell

Model STC is a $\pm$0.025% accurate unsaturated standard cell. Temperature coefficient is $-$.00001v/°C. Internal resistance is below 1200 ohms. Available mounted (3¼" dia. x 3" high) or unmounted (1" W x 3" L).

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PRELIMINARY SPECIFICATIONS

Sensitive Research* INSTRUMENTS

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SINGER METRICS DIVISION, THE SINGER COMPANY, 915 PEMBROKE ST., BRIDGEPORT 8, CONNECTICUT

STERLING CO.

MODEL
LTC-2

MODULARIZED AC/DC CALIBRATION STANDARD

This new AC-DC current/voltage calibration standard features high speed operation up to 25kc and digital readout. Designed for 19" rack or bench mounting, the console covers a range of 1mv to 1000v and 1μa to 10 amps. Readout is in "% error" or actual values, (6 digits in steps of 1mv on voltage and 5 digits in steps of 100μa on current, except on current below 100μa, 6 digits with 1μa resolution).

To reduce calibration time a thermocouple reference circuit with better than 0.01% stability per hour has been designed. This permits direct AC readings without frequent AC-DC transfer.

A $\pm$100 PPM accurate solid state 1 volt standard source is self contained. Stability of this reference is guaranteed for a period of 30 days although data acquired over the last four years indicates in most cases it maintains its accuracy for a period of 1 year or more. Two binding posts are furnished for a quick external check of this 1 volt source. An adjustment can easily be made by the user to better than $\pm$5 PPM if necessary.

A panel instrument with a 5" scale reading in "Percent" monitors the input to the console. In operation, thermocouple overloading is prevented by inserting this monitor by switch before applying a signal to the thermoelement in the measuring circuit. At the same time the reference thermoelement in the console is put on "heat" and is ready for use when the thermoelement in the measuring circuit is substituted for the monitor.

continued

The galvanometer is oil damped and relatively free from the effects of vibration. It has a clearly defined light spot and front panel zero control over its entire scale.

The Model LTC-2 is designed around a double thermocouple measurement circuit. The double or "differential" thermocouple circuit utilizes one thermocouple to measure and a second thermocouple as a millivolt reference. Both thermocouples have closely matched characteristics and when the outputs are connected in series the variations of one thermocouple with temperature are completely nullified by the second thermocouple. In use, the heater of one thermocouple is fed by the input voltage or current to be measured and the heater of the other thermocouple is fed by a regulated Zener voltage reference. For standardization purposes, both thermocouples are fed by the reference. A thermally lagged enclosure houses both thermocouples to improve temperature stability. The converters are embedded in holes in a small copper block to reduce the thermal gradient between them. A layer of foamed-plastic insulation holds the block within an external insulated enclosure.

The double conversion described permits a measurement free from the effects of temperature variations by using a differential connection. The approach simplifies the equipment and also reduces the time required to make AF measurements to high accuracies. The differential thermocouple principle was developed by J. E. Griffin and F. L. Hermach of the National Bureau of Standards.

The Sensitive Research Model LTPS-10 is the suggested AC source. It is a low distortion (0.1%), ultra stable (0.1%), wide frequency (20cps to 20kc) AC power supply furnished for standard 19" rack mounting (if desired) in a bench type grey aluminum case. It is more completely described in Section 1 of the Sensitive Research Catalog #75. DC sources are not supplied. Requirements are listed below under "Additional Specifications."

The LTC-2 console is completely shielded and installed in a durable formica case. Compact — versatile — rugged, it is a Calibration Standard in both appearance and function.

ADDITIONAL SPECIFICATIONS

Accuracy: .2v to 1110 volts ±.035% DC to 500 cycles
2ma to 11.10 amps ±.035% DC to 500 cycles
1mv to .2 volt ±.1% for DC to 500 cycles
1μa to 2 ma ±.1% for DC to 500 cycles
All ranges useable to higher frequencies (up to 25kc in most instances) at slightly reduced accuracies.

Response: True RMS.

Type: Double thermoelement.

Sources required:

1. Current source to supply instrument to be calibrated plus 2v. drop in console. AC and DC.
2. Voltage source to supply instrument to be calibrated plus .01 amps consumed in console. AC and DC.
3. 115v, 60 cycle (approx. 50 VA) required for internal references in console.

Case: Formica; walnut finish.

Panels: Black anodized aluminum.

Size (includes bench case):
16" x 20½" x 16" high, can be assembled in a standard 19" rack.

Weight: Approx. 50 lbs.

Price: $3500.00

Terms: Net 30 days F.O.B. Bridgeport, Conn.

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NEW!

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LTC-2

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2ma to 11.10 amps ±.035% DC to 500 cycles
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Type: Double thermoelement.

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2. Voltage source to supply instrument to be calibrated plus .01 amps consumed in console. AC and DC.
3. 115v, 60 cycle (approx. 50 VA) required for internal references in console.

Case: Formica; walnut finish.

Panels: Black anodized aluminum.

Size (includes bench case):
16" x 20½" x 16" high, can be assembled in a standard 19" rack.

Weight: Approx. 50 lbs.

Price: $3500.00

Terms: Net 30 days F.O.B. Bridgeport, Conn.

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Sensitive Research

CATALOG NO. 75

GENERAL INDEX

The following explanation concerning the layout of Catalog No. 75 is to assist the user in promptly locating the instrument of his choice.

The catalog contains separate sections numbered consecutively from 1-12, plus this index containing general information about Sensitive Research, its policies and products. The instruments listed in each section are grouped together because of similarities in function and/or construction. Each section is classified under a general heading. Their first page contains a section number printed in the upper right hand corner and a separate index giving model, description and exact page numbers for each instrument catalogued therein.* In cases where no specific grouping is possible because of some characteristic peculiar to the application or function of particular equipment, instruments are catalogued under the general heading "Special Purpose Instruments."

The Index of Catalog Sections lists a "New Instrument" section which is provided simply for the temporary insertion of additional data sheets as new products become available. Later catalog printings are to include these instruments in their proper sections. If a specific item cannot be located in the general indexes, consult that part of the catalog reserved for "New Instruments" (Section 12).

Information regarding the availability of portable instruments in "Edgewise Panel Cases" (for vertical panel mounting) is contained in the descriptions of portables. When attempting to locate a model with the suffix "EW-5A" or "EW-7A" in its nomenclature, consult the listings for the model letters preceding this designation (e.g.: Model CEW-7A; look up "Model C" in the index of model names).

"Accessory" items which have application in conjunction with a variety of instruments are listed in a separate section so entitled. However, specific accessories such as replacement thermocouples, special power supplies and other such products are listed in the description of the instrument with which they are mainly designed to be used.

Each catalog section is assigned a block of consecutively numbered pages. However, the present section may occupy only a portion of those allotted. This is to permit the proper location of new instruments in future catalog printings.

Prices for each instrument or accessory item are listed with their specifications.

Indexes are cross-referenced as follows:

(1) Index by Catalog Sections
(2) Index by Instrument Description—Alphabetical
(3) Index by Model and Trade Name—Alphabetical
(4) Index of COMMANDER Instruments by Type Number—Numerical

Note: As a further convenience to those who frequently reference the catalog, a set of section dividers and/or an index of instrument code words are available upon written request to Sensitive Research in New Rochelle, New York.

*Some editions of Catalog No. 75 were issued before Section 6, "Electrostatic Voltmeters" was reprinted in the new format with a first page index.

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INDEX BY CATALOG SECTIONS

Sect.	Titles and List of Models	Pages
	Indexes and general information	1 to 50
1	**Laboratory Standard Electrical Indicating Instruments, Test Consoles and Calibrators.** *Models:* B, BS-1, CHC, DYL, FLH, FLH-5M, INCRE, L, LE, LT-2M, LT-10M, LTC-1, LTCA-1, LTPS-10, LW, PC, PCM, PC-R, PC-S, RFVC, STV, THACH, THACH-PS	51 to 150
2	**Portable and Rack Panel Mounted AC, DC and AC/DC Polyrangers** (Multirange Instruments To Measure Current and Voltage). *Models:* A, C, DYP, NPR, S, U-88, University, USP, U-SP, UVA, UX, WVA	151 to 200
3	**Portable and Panel Direct Current Permanent Magnet, Moving Coil** Microammeters, Milliammeters, Ammeters, Millivoltmeters, Voltmeters, Kilovoltmeters, and Universal DC Test Set. *Models:* C, HS, J, JW-4A, JWSP, N, NP, S, University, UP, UPP, UTS	201 to 250
4	**Portable and Panel AC/DC and AC Reference Standard Dynamometer and Moving Iron** Ammeters, Milliammeters and Voltmeters. *Models:* D, MI, NSI, University	251 to 300
5	**Portable and Panel AC/DC Single Phase and Polyphase Electrodynamometer Wattmeters,** Universal AC Test Sets, Power Factor Instruments and Volt-Amp-Wattmeters. *Models:* Compensating Inductors, DLW, DW, PDLW, PDW, PF, PPF, U60AC, U400AC, U1000AC, University, VAW, "Y" Boxes	301 to 350
6	**Portable and Panel AC/DC Electrostatic Voltmeters** for RMS and Peak Voltage Measurements. *Models:* CRV, ESD, ESH, University, VPA	351 to 400
7	**Portable and Panel AC/DC Audio and Radio Frequency Thermocouple** Milliammeters, Ammeters, and Voltmeters. *Models:* A, AU, AUV, RF, RFV, T, TM, TX, University, XT	401 to 450
8	**Portable and Panel Magnetic Testing Instruments,** Fluxmeters, Flux Voltmeters, Universal Magnetic Testing Set, AC Core Loss Test Set and Fluxmeter Calibrator. *Models:* COL, EPS, FC, FCM, FM, FS, FLV, FLVC, GPS, MAT, MU, STM	451 to 500
9	**Portable and Panel AC and DC and AC/DC Special Purpose Electrical Indicating Instruments** (Potentiometer Voltmeters; Differential, Ratio, Frequency, Current Product, Zero Resistance, and Form Factor Meters; Scale Drawing Machine). *Models:* DYSP, E, FRE, JD, JDJW-4A, PV, RA, SCAMA, SD, ZR	501 to 600
10	**Instrument Accessories** (Thermoelements; Shunts; Multipliers; Unsaturated Standard Cell; Switches; Transformers). *Models:* MUL, SH, STC, T, TR, TX, Types 9145 & 9630	601 to 650
11	**COMMANDER Instruments** (Amplifiers; Choppers; Comparators; Constant Temperature Enclosures and Saturated Standard Cells; Current Controller; Galvanometers; Low Thermal Switches; Potentiometers; Standard Resistors; Temperature Measuring Equipment; Volt Ratio Boxes). *COMMANDER instruments are listed by type rather than model. See listing on page 6.*	11-1 to 11-50
12	NEW INSTRUMENTS	

INDEX BY INSTRUMENT DESCRIPTION

LEGEND

dyn.	electrodynamometer	**pmmc**	permanent magnet, moving coil
electro.	electrostatic	**rect.**	rectifier
EW panel	edgewise panel	**therm.**	thermocouple
mov. iron	moving iron	**trans.**	transformer

ACCESSORIES

Description	Model	Type	Accuracy	Scale	Sect.	Page
Vacuum Thermocouples; contact and insulated	T	—	—	—	10	601-602
Air thermocouples	TX	—	—	—	10	601-602
Thermocouple unit; multirange	TM	—	—	—	7	411
Low Thermal Switch (COMMANDER)	9145	—	—	—	10	602
Dual Contact Copper Switches (COMMANDER)	9630	—	—	—	10	602
Choppers; mechanical; low thermal (COMMANDER)	9742-3-4	—	—	—	11	11-1 to 11-50
Current Shunts; laboratory standard	SH	—	.05% & .1%	—	10	603
Voltage Multipliers; laboratory standard	MUL	—	.05% & .1%	—	10	603
Voltage Multipliers (for Model CRV)	—	—	1%	—	6	351-362
Current Transformers	TR	—	.25% ratio	—	10	604
Standard Cell; miniature; unsaturated	STC	—	.025%	—	10	604
Epstein Frame	EPS	—	—	—	8	461
Calibrating magnet & search coil	FCM	—	.5%	—	8	452
Standard magnet	STM	—	1%	—	8	452
General purpose search coil	GPS	—	—	—	8	452
Compensating inductors	—	—	—	—	5	312
Mutual inductors	MU	—	—	—	8	461
Probe, high voltage	—	—	—	—	3	212
"Y" Boxes	—	—	.1%	—	5	304

AMMETERS—MILLIAMMETERS—MICROAMMETERS (See also "Volt-Amp-Milliammeters")

Laboratory Standard	B	DC, pmmc	.1%	12"	1	66
Laboratory Standard ammeters; self contained	CHC	DC, pmmc	.2%	6.3"	1	69
Portable & EW panel	C	DC, pmmc	.25%	6.3"	3	202-203
Portable & EW panel; high sensitivity	S	DC, pmmc	.5%	6.3"	3	204-205
Portable	N	DC, pmmc	.25% & .5%	6.1"	3	207-208
Rectangular panel	NP	DC, pmmc	.5%	6.1"	3	208-209
Portable; small	University	DC, pmmc	.5%	4"	3	210-211
Portable and bench type	J	DC, pmmc	.5%	3.25"	3	213
EW panel; small; binding posts only	JW-4A	DC, pmmc	.5%	4"	3	216-217
EW panel; small; switch controlled	JWSP	DC, pmmc	.5%	4"	3	217
Rectangular panel	UPP	DC, pmmc	.5% & 1%	4"	3	214-215
Portable and bench type; differential	JD	DC, pmmc	.5%	3.25"	9	503
EW panel; small; differential	JDJW-4A	DC, pmmc	.5%	4"	9	504
Portable & EW panel; differential	SD	DC, pmmc	.5%	5.2"	9	502-503
Portable; zero resistance	ZR	DC, pmmc	.5%	5.2"	9	508
Portable & EW panel; ratiometer	RA	DC, pmmc	.25%	5.2"	9	505
Portable & EW panel	MI	AC, mov. iron	.5%	6.3"	4	256
Portable	NSI	AC, mov. iron	.5%	6"	4	257
Laboratory Standard	L	AC/DC, dyn.	.1%	12"	1	67
Portable & EW panel	D	AC/DC, dyn.	.25%	6.3"	4	252-254
Portable; small	University	AC/DC, dyn.	.5%	4"	4	255
Portable & EW panel	A	AC/DC, therm.	.5% & .75%	6.3"	7	404-405
Portable & EW panel; audio freq.	AU	AC/DC, therm.	.5% & .75%	6.3"	7	406
Portable & EW panel; radio freq.	RF	AC/DC, therm.	.5%, .75% & 1%	6.3"	7	407-409
Portable; small	University	AC/DC, therm.	.75%	4"	7	412

CALIBRATORS—CONSOLES—ACCESSORY POWER SUPPLIES—REFERENCE SOURCES

Calibration Console (Separate AC & DC)	LTC-1	AC/DC, therm. transfer	.05% (of reading)	—	1	52-55
Calibration Console	LTCA-1	AC/DC, therm. transfer	.05% (of reading)	—	1	55
Power Supply; low distortion	LTPS-10	AC, 20 cps to 20 kc	—	—	1	55
Voltage Transfer Standard	FLH	AC/DC, therm.	.01% (of reading)	—	1	56-57
Portable & EW panel; VTVM Calibrator; radio freq.	RFVC	AC/DC, therm.	.5%	6.3"	1	72-73
Lindeck Microvolt Source	LE	DC, pmmc	±(.35%+.05 μv)	6.3"	1	73-74
Portable & panel; Voltage Standard	STV	DC Zener source	.01% of output	—	1	60
Portable & panel; Fluxmeter Calibrator	FC	DC	.2% of output	—	8	455
Laboratory Standard; "Self Checking"	THACH	AC/DC, therm.	.2%	6.3"	1	61-64
Volt-Amp-Milliammeter & Power Supply	THACH-PS	DC, 60, 400 cps source	—	—	1	64
Unsaturated Standard Cell, miniature	STC	—	.025%	—	10	604
Saturated Standard Cells in Constant Temperature Enclosures	9152 & 9152A	air bath	.0001%, ±.01°C bath	—	11	11-1 to 11-50
Portable Saturated Std. Cell Enclosure	9152P	air bath	.0001%, ±.01°C bath	—	11	11-1 to 11-50

Description

CHOPPERS (See "Accessories")

COMMANDER INSTRUMENTS
(See COMMANDER model listings on page 6)

CORROSION INSTRUMENTS (See "Potentiometers, Portable"—Models PC & PCM; "Voltmeters"—Models HS & ESD; "Special Purpose Instruments"—Models PV and ZR)

Description

DIFFERENTIAL INSTRUMENTS
(See "Special Purpose Instruments")

ELECTROLYSIS INSTRUMENTS (See "Special Purpose Instruments" — Models ZR & PV; "Potentiometers, Portable"—Models PC & PCM; "Voltmeters"—Model HS)

ELECTROSTATIC VOLTMETERS

Description	Model	Type	Accuracy	Scale	Sect.	Page
Portable and panel	ESH	AC/DC, electro.	.5% & 1%	6"	6	351-362
Portable & EW panel	ESD	AC/DC, electro.	.5% & 1%	5.2"	6	351-362
Portable; small	University	AC/DC, electro.	1%	4"	6	351-362
Portable; peak or rms	CRV	AC/DC, electro.	1%	5.2"	6	351-362
Multipliers for Model CRV	—	—	1%	—	6	351-362
Peak adaptors for electro. voltmeters	VPA	—	—	—	6	351-362

Description

EPSTEIN FRAME (See "Magnetic Testing Instruments")

FLUXMETERS (See "Magnetic Testing Instruments")

FLUXMETER CALIBRATOR
(See "Magnetic Testing Instruments")

FLUX VOLTMETERS
(See "Magnetic Testing Instruments")

FORM FACTOR INSTRUMENT
(See "Special Purpose Instruments")

Description

FREQUENCY METERS
(See "Special Purpose Instruments")

GALVANOMETERS (See "Special Purpose Instruments"—Models JD, JDJW-4A, SD; "Microammeters" and "Millivoltmeters"—Models J, JW-4A; "COMMANDER Instruments")

GAUSSMETERS
(See "Magnetic Testing Instruments"—fluxmeters)

INDUCTORS Mutual (See "Magnetic Testing Instruments"); Compensating (See "Wattmeters")

LINDECK MICROVOLT SOURCE (See "Calibrators"—Model LE; "COMMANDER Instruments"—Type 9174)

MAGNETIC TESTING INSTRUMENTS AND ACCESSORIES

Description	Model	Type	Accuracy	Scale	Sect.	Page
Universal Magnetic Testing Set	MAT	AC/DC to meas. E, I, watts & flux	.5%-1%	4"	8	459-461
Core Loss Test Set	COL	AC to meas. E, I and watts	.5%-1%	4" & 6.3"	8	462
Epstein Frame	EPS	25 cm	—	—	8	461
Portable & EW panel; fluxmeter; multirange	FM	DC, pmmc	.5%	5.2"	8	452-454
Portable & EW panel; fluxmeter; single range	FS	DC, pmmc	.5%	5.2"	8	452-454
Portable & Rack panel; fluxmeter calibrator	FC	DC	.2% of output	—	8	455
Portable & EW panel; flux voltmeter	FLV	AC, rect.	.5%	6.3"	8	456
Portable & EW panel; flux voltmeter	FLVC	AC, rect.	.25%	6.3"	8	456
General purpose search coil	GPS	—	—	—	8	452
Standard magnet	STM	—	1%	—	8	452
Calibrating magnet & search coil	FCM	—	.5%	—	8	452
Mutual Inductors	MU	—	—	—	8	461

Description

MICROAMMETERS (See "Ammeters")

MICROVOLTMETERS (See "Calibrators"—Model LE; "COMMANDER Instruments"—Potentiometers)

MILLIAMMETERS (See "Ammeters")

MILLIVOLTMETERS (See "Voltmeters")

MULTIPLIERS (See "Accessories")

Description

PANEL INSTRUMENTS
(See individual model descriptions for availability of edgewise panel and rack panel mounted instruments)

PANEL INSTRUMENTS, RECTANGULAR
(See "Ammeters" and "Voltmeters"—Models UPP & NP)

POLYRANGERS (See "Volt-Amp-Milliammeters")

POTENTIOMETERS (See "COMMANDER Instruments" and "Potentiometers, Portable")

POTENTIOMETERS, PORTABLE—"PLUG-IN" ACCESSORIES

Description	Model	Type	Accuracy	Scale	Sect.	Page
Miniature Potentiometer; "PocketPot"	PC	DC	.05% (of reading)	—	1	58
Multirange Miniature Potentiometer; "PocketPot"	PCM	DC	.05% (of reading)	—	1	59
Current-Volt Range Extension Box for use with "PocketPot"	PC-S	DC	.05% (of reading)	—	1	59
Wheatstone Bridge for use with "PocketPot"	PC-R	DC	.2% (of reading)	—	1	59

Description

POTENTIOMETER VOLTMETER
(See "Special Purpose Instruments"—Model PV)

POWER FACTOR INSTRUMENTS

Description	Model	Type	Accuracy	Scale	Sect.	Page
Portable & EW panel; power factor meter; single phase	PF	AC, dyn.	.005 PF	6.3"	5	307
Portable & EW panel; power factor meter; polyphase	PPF	AC, dyn.	.005 PF	6.3"	5	307

Description

POWER SUPPLIES AND REFERENCE SOURCES (See "Calibrators")

PROBE, HIGH VOLTAGE (See "Accessories")

RATIOMETERS
(See "Special Purpose Instruments"—Model RA)

Description

SCALE DRAWING MACHINE (Model SCAMA—See Catalog Section 9, Pg. 511)

SHUNTS (See "Accessories"—Model SH; "COMMANDER Instruments"—Types 1659, 1682, 3111, 9200)

SPARE PARTS (Replacement thermoelements listed with thermocouple instruments. Spare parts are available for all instruments)

SPECIAL PURPOSE INSTRUMENTS

Description	Model	Type	Accuracy	Scale	Sect.	Page
Portable & EW panel; frequency	FRE	AC, transducer-coupled pmmc	.25%	6.3"	9	509
Portable & EW panel; current product	DYSP	AC/DC, dyn.	.25%	5.2"	9	506
Portable & EW panel; form factor	E	AC/DC, therm. & rect.	.2%	6.3"	9	510
Portable & EW panel; differential	SD	DC, pmmc	.5%	5.2"	9	502-503
Portable bench type; differential	JD	DC, pmmc	.5%	3.25"	9	503
EW panel; differential	JDJW-4A	DC, pmmc	.5%	4"	9	504
Portable & EW panel; ratiometers	RA	DC, pmmc	.25%	5.2"	9	505
Portable potentiometer voltmeters	PV	DC, pmmc	.35%	5.2"	9	507
Portable zero resistance; current	ZR	DC, pmmc	.5%	5.2"	9	508

Description

STANDARD CELL ENCLOSURES & CELLS
(See "COMMANDER Instruments"—Types 9152, 9152A, 9152P)

Description

STANDARD RESISTORS (See "Shunts")

TEST SETS, PORTABLE

Description	Model	Type	Accuracy	Scale	Sect.	Page
Universal DC Test Set	UTS	DC, to meas. E, I, & R	.5%	4"	3	218-219
Universal AC Test Set; 50-60 cps	U60AC	AC, to meas. E, I, & watts	.5% & .75%	4"	5	314-315
Universal AC Test Set; 50-400 cps	U400AC					
Universal AC Test Set; 25-1000 cps	U1000AC					
Universal Magnetic Testing Set	MAT	AC/DC, to meas. E, I, watts & flux	.5%-1%	4"	8	459-461
Core Loss Test Set	COL	AC, to meas. E & I	.5%-1%	4" & 6.3"	8	462

Description

THERMOCOUPLES (See "Accessories")

THERMOMETER BRIDGE
(See "COMMANDER Instruments")

Description

TRANSFER STANDARD (See "Calibrators")

TRANSFORMERS (See "Accessories")

VOLT-AMP-MILLIAMMETERS

Description	Model	Type	Accuracy	Scale	Sect.	Page
Portable & EW panel; Self Checking; 51 ranges	UX	*AC/DC, therm.	.5% AC & DC	5.2"	2	154-155
Portable & EW panel; 88 ranges	U88	*AC/DC, therm.	.5% DC; .75% AC	5.2"	2	156-157
Portable & EW panel; 28 ranges	USP	*AC/DC, therm.	.5% DC; .75% AC	5.2"	2	158-159
Portable & EW panel; 31 ranges	U-SP	*AC/DC, therm.	.5% DC; .75% AC	5.2"	2	159
Portable & EW panel; 11-14 ranges	A	AC/DC, therm.	.75%	6.3"	2	160
Portable & EW panel; 12-20 ranges	DYP	AC, trans. coupled dyn.	.3%	6.3"	2	166
Portable & EW panel; 22 ranges	UVA	AC, trans. coupled mov. iron; DC, pmmc	.5% DC; .75% AC	4"	2	161
Portable & EW panel; 14 ranges	C	DC, pmmc	.25%	6.3"	2	163
Portable & EW panel; 27 ranges	WVA	DC, pmmc	.25%	6.3"	2	162
Portable & EW panel; 13 ranges; high sensitivity	S	DC, pmmc	.5%	5.2"	2	164
Portable and panel; 9-11 ranges	NPR	DC, pmmc	.5%	6.1"	2	165
Portable; small; 9 ranges	University	DC, pmmc	.5%	4"	2	165
Laboratory Standard; Self Checking	BS-1	DC, pmmc	.05%	12"	1	65
Laboratory Standard; Self Checking	THACH	AC/DC, therm.	.2%	6.3"	1	61-64
Laboratory Standard	DYL	AC, trans. coupled dyn.	.1%	12"	1	69
Laboratory Standard; expanded scale	INCRE	DC, pmmc	.05%	63" (effective)	1	70-71

*Polyrangers with separate AC/DC and DC only measuring ranges

VOLT-AMMETERS (See "Volt-Amp-Milliammeters")

VOLT-AMP-WATTMETER (See "Wattmeters")

VOLT RATIO BOXES (See "COMMANDER Instruments")

VOLTMETERS—KILOVOLTMETERS—MILLIVOLTMETERS

(See also "Electrostatic Voltmeters"; "Volt-Amp-Milliammeters"; "Volt Ratio Boxes"; "Calibrators")

Laboratory Standard	B	DC, pmmc	.1%	12"	1	66
Lindeck Microvolt Source	LE	DC, pmmc	±(.35%+.05 μv)	6.3"	1	73-74
Portable & EW panel	C	DC, pmmc	.25%	6.3"	3	202-203
Portable & EW panel; high sensitivity	S	DC, pmmc	.5%	6.3"	3	204-205
Portable & EW panel; ultra high sensitivity	HS	DC, pmmc	.5%	6.3"	3	206
Portable	N	DC, pmmc	.25% & .5%	6.1"	3	207-208
Rectangular panel	NP	DC, pmmc	.5%	6.1"	3	208-209
Portable; small	University	DC, pmmc	.5%	4"	3	210-211
Portable & bench type; millivoltmeters	J	DC, pmmc	.5%	3.25"	3	213
EW panel; small; binding posts only	JW-4A	DC, pmmc	.5%	4"	3	216-217
EW panel; small; switch controlled	JWSP	DC, pmmc	.5%	4"	3	217
Rectangular panel	UPP	DC, pmmc	.5% & 1%	4"	3	214-215
Portable & EW panel; kilovoltmeters	DCHI	DC, pmmc	.5% & 1%	4"	3	212
Portable & EW panel; differential	SD	DC, pmmc	.5%	5.2"	9	502
Portable; potentiometer type	PV	DC, pmmc	.35%	5.2"	9	507
Portable & EW panel	MI	AC, mov. iron	.5%	6.3"	4	256
Portable	NSI	AC, mov. iron	.5%	6"	4	257
Portable & EW panel; average reading	FLV	AC, rect.	.5%	6.3"	8	456
Portable & EW panel; average reading	FLVC	AC, rect.	.25%	6.3"	8	456
Laboratory Standard	L	AC/DC, dyn.	.1%	12"	1	67
Portable & EW panel	D	AC/DC, dyn.	.25%	6.3"	4	252-254
Portable; small	University	AC/DC, dyn.	.5%	4"	4	255
Portable & EW panel	A	AC/DC, therm.	.5% & .75%	6.3"	7	404-405
Portable; audio frequency	AU	AC/DC, therm.	.5% & .75%	6.3"	7	406
Portable; radio frequency	RF	AC/DC, therm.	.5%	6.3"	7	409-410
Portable; small	University	AC/DC, therm.	.75%	4"	7	412

WATTMETERS (See also "Test Sets, Portable"—Models U60AC, U400AC, U1000AC)

Laboratory Standard wattmeters; single phase	LW	AC/DC, dyn.	.1%	12"	1	68
Portable & EW panel; wattmeters; single phase	DW	AC/DC, dyn.	.25%	6.3"	5	304
Portable & EW panel; wattmeters; single phase; low PF	DLW	AC/DC, dyn.	.5%	5.2"	5	305
Portable wattmeters; single phase; small	University	AC/DC, dyn.	.5% & .75%	4"	5	306-307
Portable & EW panel; wattmeters; 3 phase	PDW	AC/DC, dyn.	.5%	6.3"	5	312
Portable & EW panel; wattmeters; 3 phase; low PF	PDLW	AC/DC, dyn.	.75%	5.2"	5	313
Volt-Amp-Wattmeters	VAW	AC, trans. coupled dyn.	.5% & .75%	5.2"	5	308-309
"Y" Boxes	—	—	—	—	5	304
Inductors, Compensating	—	—	—	—	5	312

"Y" BOXES (See "Wattmeters")

ZENER REGULATED VOLTAGE SOURCE

(See "Calibrators")

ZERO RESISTANCE INSTRUMENTS

(See "Special Purpose Instruments")

ALPHABETICAL INDEX BY MODEL AND TRADE NAME

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A Polyranger (Comb. 1-AA, 1-AB, 1-AC, 1-AD, 2-A, 3-A)	2	106
AU	7	406
AUV (See Model AU)		
B	1	66
BS (See BS-1)		
BS-1 (Self Checking Volt-Amp-Milliammeter)	1	65
C	3	202-203
C Polyranger (Comb. 1-C, 2-C, 3-C)	2	163
CHC	1	69
COL	8	462
CRV	6	351-362
D	4	252-254
DCHI	3	212
DLW	5	305
DW	5	304
DYL	1	69
DYP Polyranger (Comb. 1 & 2)	2	166
DYSP	9	506
E	9	510
EPS	8	461
ESD	6	351-362
ESH	6	351-362
FC	8	455
FCM	8	452
FLH	1	56-57
FLH-5M	1	57
FLV	8	456
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FRE	9	509
FS	8	452-454
GPS	8	452
HS	3	206
INCRE (Incremeter)	1	70-71
J	3	213
JD	9	503
JDJW-4A	9	504
JW-4A	3	216-217
JWSP	3	217
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LE	1	73-74
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LT-10M	1	55
LTC-1	1	52-55
LTCA-1	1	55
LTPS-10	1	55
LW	1	68
MAT	8	459-461
MI	4	256
MU	8	461
MUL	10	603
N	3	207-208
NP	3	208-209
NPR Polyranger (Comb. 1-NPR, 2-NPR, 3-NPR)	2	165
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PC (PocketPot)	1	58-59
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PC-S	1	59
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PDW	5	312
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PocketPot (Models PC, PCM)	1	58-59
Polyranger (Models A, C, DYP, NPR, S, University, USP, U-SP, UVA, UX, U88, WVA)	2	151-200
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PV (Rhodes Potentiometer Voltmeter)	9	507
RA	9	505
RF	7	407-410
RFV (See Model RF)		
RFVC	1	72-73
Rhodes Potentiometer Voltmeter (Model PV)	9	507
S	3	204-205
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SH	10	603
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T	7 & 10	411 & 602
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ZR	9	508

NUMERICAL LISTING OF COMMANDER INSTRUMENTS

(ALL COMMANDER INSTRUMENTS ARE DESCRIBED IN SECTION 11)

Type No.	Description
1659 and 1682	Four Terminal Resistor
3111	Four Terminal Resistor
4281 A-G	Volt Ratio Box
4363D	Potentiometer
4500/SR4	Galvanometer
5180	Galvanometer
5214	Galvanometer Amplifier
5214A	Thermal Compensator
5558	Drysdale Wattmeter
9120	Potentiometer
9144	Dauphinee Potentiometer
9145	Low Thermal Switch
9152	Standard Cell Enclosure
9152A	Standard Cell Enclosure
9152P	Standard Cell Enclosure
9174	Potentiometer
9180	Potentiometer
9200	Four Terminal Resistor
9411	Galvanometer
9500	Temperature Meas. Bridge
9600	Reversing Switch
9630	Dual Contact Switch
9700	Volt Ratio Box
9700A	Volt Ratio Box
9742	Low Thermal Chopper
9743	Low Thermal Chopper
9744	Low Thermal Chopper
9770	Current Controller
9790	DC Amplifier
SR4/4500	Galvanometer
SR21	Galvanometer

Vincent Cronin David Wolf

A MESSAGE FROM THE FOUNDERS

The publication of this catalog marks, almost to the day, the completion of 35 years of precision instrument manufacturing at Sensitive Research. Catalog No. 75 seemed a long way off back in 1927 when this company initially placed a sign outside its small manufacturing premises in New York City and published Catalog No. 1, a four page brochure that contained a description of some basic DC instruments and a spirited slogan as to the intent and dedication of its people.

Many things have changed since that first day. The 4 simple instruments described in that initial catalog have grown to a product line consisting of over 4000 items ranging from precision panel and portable electrical indicating instruments to the most sophisticated laboratory standards. AC, DC and AC/DC designs, including those that operate accurately in the UHF region, are now offered to measure voltage, current, power, power factor, wave form factor, frequency, magnetic flux, core loss and numerous other parameters. Electrical indicating instruments are available in many different basic constructions. The COMMANDER instrument line contains some of the finest fundamental standards and comparators in the world.

The simple instrument, with a few ranges that measured a basic quantity, has become decidedly more complex. As many as 88 AC/DC ranges are now self contained in a portable Polyranger; modern components are included in designs to provide such features as "Self Checking," expanded scales and automatic overload protection; standard instruments measure the addition, subtraction, multiplication and division of two inputs. With such an increased product line, Sensitive Research itself has expanded manyfold into a world wide organization encompassing over 50 sales and service offices. Its initial modest production facility has become the modern manufacturing plant and laboratory presently located in New Rochelle.

However, with all of these changes that first slogan printed in Catalog No. 1, summing up the aims and hopes of this company, is still valid for reiteration in Catalog No. 75 . . . 36 years later. It reads as follows:

> *"The purchaser can consider a Sensitive Research instrument a lifetime investment whose quality will remain long after its purchase price has been forgotten."*

The reputation already established by Sensitive Research in the electrical measurements field bears out a strict adherence to this principle. It is the object of this Company's management to maintain such a philosophy in the coming years.

David Wolf — President

Vincent P. Cronin — Director of Engineering

SUGGESTIONS FOR ORDERING

1. When ordering please specify model, code word and price. A code word (or in a few cases a type number) is included for most instruments and eliminates the need for detailed descriptions. Supply any additional information requested in the instrument descriptions—i.e. sensitivity of voltmeters in Ω/v when a choice is given. Example: Model C, Code COLZO, Sensitivity 5000 Ω/v, Price $262.00.

When code words are not listed it is because a single set of specifications only apply to a particular model and no further designation is necessary or, as in shunts, multipliers, switches and etc., so many alternatives are available that it is simpler to order by model and description.

When ordering COMMANDER instruments, please specify by type number and list price. When alternate specifications are listed under the same type number, such as occurs in galvanometers (choice of coil resistance) and shunts (choice of range and watt rating), please supply this additional descriptive information.

To prevent any misunderstanding of purchase orders requesting variations in catalog specifications or standard best commercial packaging, include a detailed description of the special features desired. It is always a good procedure to request a quotation on such items prior to ordering. If an instrument has been quoted previously, noting this on the purchase order speeds up processing.

If an exact duplicate is desired of an instrument previously furnished, please provide the serial number and model of the existing instrument to prevent any misunderstanding regarding specifications, e.g.: "Model C, same as S/N 900000 previously supplied." Production cards are maintained at SRIC detailing the electrical circuit, mechanical design and performance characteristics of every instrument manufactured since 1927.

Advance purchase orders (APO's) via telephone, telegram, or TWX are honored as regular orders as a service to customers requiring expedited delivery. APO's can be placed directly on SRIC or its local representative. Please mark "Confirming" paperwork to prevent duplication.

Communications with Sensitive Research can be established as follows:

Telephone: 914 BE 5-2300
Telegram: WUX, New Rochelle, N. Y.
TWX: 914-235-3425

Telephone numbers of SRIC representatives are listed on the last page of this catalog.

2. Make out all orders (including those for COMMANDER items) emanating from the United States and its possessions to Sensitive Research Instrument Corporation and address them c/o the local SRIC representative or, if preferred, directly to 310 Main Street, New Rochelle, N. Y. (SRIC sales organizations are listed on the last page of this catalog.) When a purchase order is sent through a local representative's office, specifications, price and delivery requirements are checked before forwarding to SRIC. Representatives have copies of all quotations made directly from the factory.

Orders emanating from Canada can be placed either on SRIC or its Canadian representative. **All other orders emanating from outside the United States and its possessions** must be placed directly on Sensitive Research's export representative. FAS, CIF, C&F, etc. quotations or pro forma invoices, as well as exportation assistance are available upon request from this organization.

3. Terms for sales in the United States and its possessions (and Canada when the order is placed on Sensitive Research) are net 30 days, F.O.B., New Rochelle, N. Y., excepting as follows:

a) When NBS Certificates are specified on an order, F.O.B. point remains unchanged but transportation charges to Washington, D.C. or Boulder, Colorado are prepaid and added to the invoice. Arrangements can be made for hand carrying equipment to NBS by contacting SRIC or its representatives.

NOTE: Please specify testing at NBS as a separate item. Since final delivery is wholly dependent upon NBS and a satisfactory report is guaranteed by Sensitive Research, payment for the equipment supplied is due 30 days after shipment from SRIC.

b) When an order is placed upon SRIC for COMMANDER instruments, the F.O.B. point is Rouses Point, N. .Y When certification by the National Research Council (NRC) in Ottawa, Canada, is requested, the F.O.B. point remains the same but there is an additional charge for shipment to NRC. Terms of payment are the same as for certification at NBS. COMMANDER prices include duty at rates already established with the United States Customs. Prices quoted are subject to redetermination insofar as customs rates only are concerned. Any adjustments, either upward or downward, are passed on to the customer at cost.

All COMMANDER instruments are of Canadian origin and come under Federal Class Code 6625. In accordance with ASPR 6-103 and 6-104, the Buy American Act restriction for military procurement is waived, and COMMANDER instruments are considered as United States equipment.

Duty free certificates can be obtained for COMMANDER instruments in accordance with ASPR 6-605 (Revised Oct. 1, 1959). Where the material requisitioned is for purposes of National Defense, duty free entry can be accorded Canadian supplies upon proper application of the buyer to the cognizant contracting governmental agency. Duty free Certificates cannot be issued where the duty is less than $50.00. Special quotations are given in those cases where a duty free certificate is applicable.

Terms for sales outside the United States and its possessions (and in Canada when an order is placed on the SRIC Canadian representative) are as mutually agreed upon by the purchaser and SRIC export representative.

All prices and specifications listed in the catalog are subject to change without prior notice.

4. Spare parts are available for all instruments. Replacement thermoelements, standard cells and etc. are listed in the catalog with model descriptions. Contact SRIC for information on non-cataloged spare parts. Give nomenclature of parts and serial number of instrument in which replacement is required.

5. Shipment of instruments by Railway Express is recommended whenever possible and is the normal method employed unless other instructions are issued. If rapid delivery is required, equipment can be sent by United Parcel, air freight or air express. Component parts are normally sent by parcel post or by air parcel post if requested. **Electrical indicating instruments are shipped by parcel post only at the purchaser's demand and no responsibility can be assumed by Sensitive Research for safe arrival.** When shipment by truck is specified, please allow for considerable delays in delivery because of intermittent pickup schedules in SRIC's area and Rouses Point, N. Y. (Commander Instruments).

6. In case of receipt of material possibly damaged in transportation, please follow the general instructions enclosed with each shipment. For most commercial carriers:

a) Retain all packing materials and containers.

b) Contact the local agent of the carrier and obtain a "Joint Inspection Report." If shipped via parcel post, have the damaged shipment recorded at the local post office. This must normally be done within 15 days of receipt, or the carrier may disclaim responsibility.

c) Contact Sensitive Research, attention of the Service Manager, to arrange for return of the shipment to New Rochelle for inspection and disposition.

7. New instruments are warranted for a period of two years to be free from latent defects in materials and workmanship, providing they have not been electrically or mechanically abused and their seals are intact. Liability of Sensitive Research is limited to the replacement value of the equipment. Instruments or components under warranty are repaired or replaced (at SRIC's discretion) without charge excepting for batteries, tubes, thermoelements or other parts which have given normal service. Instruments serviced by Sensitive Research are warranted for a period not exceeding the time remaining in its new instrument warranty or for one year, whichever is the longer.

Unless specifically stated otherwise, instruments serviced by an SRIC authorized repair station are subject to the same guarantees but the responsibility for correction of out-of-warranty items is solely theirs. It is always recommended that an instrument be returned to Sensitive Research for repair and recalibration if possible.

COMMANDER instruments such as potentiometers, bridges, resistors, and shunts are warranted for a period of five years. All other COMMANDER instruments are warranted for one year. Repaired instruments, after completion of the initial warranty period, are guaranteed for a period of one year thereafter.

8. Instruments can be returned for out-of-warranty servicing directly to SRIC (recommended whenever possible) or to an authorized repair station. An extensive service facility is maintained in New Rochelle, N. Y. to repair and recalibrate any Sensitive Research instrument. When COMMANDER instruments are to be returned for servicing, contact the SRIC home office for instructions.

To assist efficient servicing and the prompt return of an instrument, please accompany it with paperwork giving model, serial number and all information pertinent to the reason for its return. Please pack the instrument securely to insure its safe arrival and ship by recommended carriers.

Before returning an instrument for in-warranty repairs, please contact SRIC or its area representative for instructions. SRIC field engineers are trained to give nominal on-the-spot service.

9. A 3 day factory seminar on the repair and recalibration of electrical indicating instruments is available to companies with a representative number of SRIC instruments to maintain. The course is designed to provide experienced technicians with intensive training in SRIC servicing procedures.

10. A Certificate of Calibration and Traceability is supplied with each new instrument. By "traceability," it is meant that calibrations have been made against SRIC standards which in turn have been certified by NBS. Surveillance of SRIC standards and quality control procedures is under cognizance of the Inspector of Naval Materials (INSMAT, N. Y.) in accordance with MIL-Q-9858.

11. Sensitive Research publishes periodically a bulletin entitled "Electrical Measurements" which covers a wide variety of topics concerning new techniques, new instruments and solutions to various measuring problems. It is available upon request at no charge.

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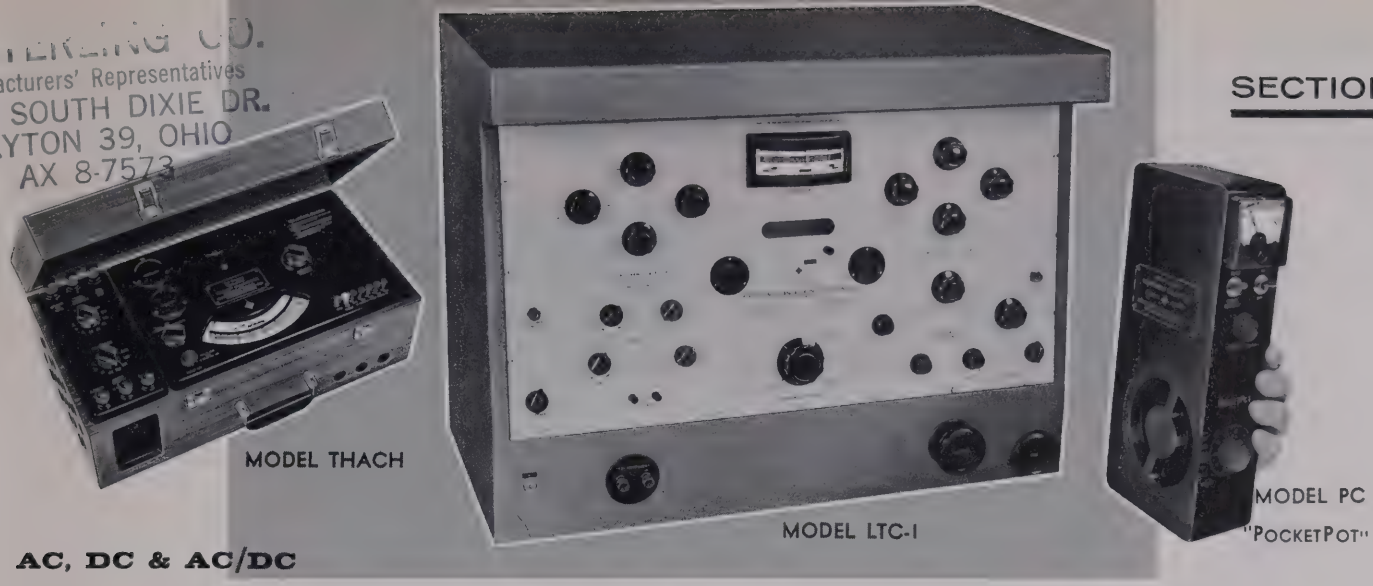


AC, DC & AC/DC

LABORATORY STANDARD
ELECTRICAL INDICATING INSTRUMENTS
TEST CONSOLES AND CALIBRATORS

Model	Description	Page
LTC-1 LTCA-1	.05% AC/DC Calibration Consoles for current and voltage measurements up to 25 kc	52-55
LTPS-10	AC Power Supply for low distortion, variable frequency operation with calibration consoles	55
FLH	.01% AC/DC Voltage Transfer Standard	56-57
PC	.05% DC Miniature Potentiometer (PocketPot)	58
PCM	.05% DC Multirange Miniature Potentiometer (PocketPot)	59
PC-S	.05% Volt-Current Range Extension Box for use with PocketPot	59
PC-R	.2% Wheatstone Bridge for use with PocketPot	59
STV	.01% DC Voltage Standard (Zener regulated source)	60
THACH	.2% AC/DC "Self Checking" Volt-Amp-Milliammeters. 6.3" scale length	61-64
THACH-PS	AC/DC Power Supply for use with Model THACH and as a general purpose source	64
BS-1	.05% DC "Self Checking" Volt-Amp-Milliammeter. 12" scale length	65
B	.1% DC Laboratory Standard Millivoltmeters, Voltmeters, Milliammeters and Ammeters. 12" scale length	66
L	.1% AC/DC Laboratory Standard Voltmeters, Milliammeters and Ammeters. 12" scale length	67
LW	.1% AC/DC Laboratory Standard Wattmeters. 12" scale length	68
DYL	.1% AC Laboratory Standard Volt-Amp-Milliammeter. 12" scale length	69
CHC	.2% DC Heavy Current Ammeters. 6.3" scale length	69
INCRE	.05% DC Expanded Scale Volt-Amp-Milliammeter. 63" effective scale length	70-71
RFVC	.5% AC/DC Radio Frequency VTVM Calibrator to 10 mc. 6.3" scale length	72-73
LE	±(.35% + .05μv) DC Lindeck Microvolt Source. 6.3" scale length	73-74
FC	.2% DC Fluxmeter Calibrator (Described in Section 8)	

Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N. Y.

Additional electrical measuring standards such as precision potentiometers, volt ratio boxes, resistors and shunts, standard cells and constant temperature enclosures, galvanometers, amplifiers, bridges, comparators and accessory equipment are listed in the COMMANDER Instrument section.

Symbol of Quality

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *Electrical Measuring Instruments Since 1927*

MODEL LTC-1
AC/DC AND DC CALIBRATION CONSOLE

MODEL LTC-1

SPECIFICATIONS

AC/DC AND DC CALIBRATION CONSOLE

ACCURACY	.05% of reading
TYPE	Modified Hermach AC/DC thermocouple transfer circuit for AC measurements. A differential circuit with a Zener stabilized reference source is used for comparisons of AC to DC and for rapid measurements of DC only.
AC RESPONSE	True rms
RANGE	A. Current: 1 ma (2 ma on AC) to 11.10 amps in steps of 1 ma B. Voltage: .5 v to 1110 v in steps of .1 v
SENSITIVITY	A. Current: 2 v drop all ranges B. Voltage: AC/DC transfer 100 Ω/v; DC only, 1000 Ω/v
FREQUENCY RANGE	DC and 10 cps to 25 kc. Frequency influence is negligible up to 500 cps for all ranges and is no greater than .05% when operation is within the following limits:

A. Current	Max. Frequency
2-499 ma	20 kc
.5-1.99 amps	10 kc
2-11.10 amps	5 kc

B. Voltage	Max. Frequency
.5-99.9 v	25 kc
100-199.9 v	20 kc
200-399.9 v	10 kc
400-1110 v	2.5 kc

READOUT	Directly in "% Error" on an indicating instrument (Incremeter) or in absolute values from the setting of the dials on the front panel. Provision is also made for connection to an external precision potentiometer if desired.
RESOLUTION	A. "% Error" Indicator: 5", 100 div. scale printed from +5% to −5%. Readily detects changes of ±.01%. B. Dial Setting: Steps of 1 ma and .1 v C. External Potentiometer: Resolution is that of the potentiometer employed.
GALVANOMETER SENSITIVITY	A deflection of 1 mm from null in AC/DC transfer measurements is equal to less than .01% of reading. Sensitivity is constant for all levels of input.
THERMOCOUPLE REPLACEMENT	Uses uncalibrated thermoelements. (See "Optional Accessories.")
SHIELDING	Electrostatic
RANGE CHANGING	Switch controlled
POWER REQUIREMENTS	A. The Model LTPS-10 is a low distortion, variable frequency AC current and voltage supply recommended for use with the Model LTC-1. Specifications are listed under "Optional Accessories." B. A 115 v, 60 cps source, two 6 v storage batteries (or equivalent) and a regulated 1000 v DC supply are required for operation but not furnished. C. Two Mallory Type RM-42R mercury batteries or equivalent (supplied mounted internally)
CASE	Aluminum; 36" w x 28" h x 20" d; annodized light gray panel; dark gray wrinkle finished cabinet; front panel light
APPROX. WEIGHT	125 lbs. net; 175 lbs. shipping

AC/DC AND DC CALIBRATION CONSOLE

GENERAL DESCRIPTION

The Model LTC-1 is a precision AC/DC calibration console that measures voltage and current to ±.05% of reading from DC to 25 kc. The console is fundamentally a Hermach type transfer standard with some important modifications to increase accuracy and ease of operation. It contains a separate, fast DC calibrator so that DC measurements do not have to be made by the thermocouple transfer method, a "% Error" readout indicator and a ±.01% accurate internal reference source. The aluminum case of the console provides a rigid, stable housing and an effective shield. Its design as an "upright" console permits an economical *one man operation.* The Model LTC-1 accuracy as stated is the actual total accuracy obtainable, since no accessory measuring equipment such as potentiometers, volt boxes and similar equipment, which pyramid this specification, is necessary. The self contained light beam galvanometer is the COMMANDER Type 9411. Sensitivity is such that a deflection of 1 mm division amounts to an AC/DC transfer error of approximately .01%. The galvanometer is oil damped and hence not subject to disturbance from normal vibration. A knob on the front panel allows for the zero adjustment of the light spot over the entire length of the galvanometer scale.

All ranges are switch controlled. Each range position is an individually calibrated point and consequently accuracy is in terms of reading rather than of full scale. The inclusion of an Incremeter* for a "% Error" readout gives the user the option of either setting an instrument under test at a particular scale value and reading the Incremeter, or nulling the Incremeter and reading the deviation on the scale of the instrument. However, it is an obvious advantage to read the Incremeter since it has an effective resolution of 10X to 20X that of most electrical indicating instruments. It is automatically protected against overloads of 500%.

Provision is also made for a potentiometric readout in those instances where greater resolution may be required. A precision potentiometer can be connected via a link system mounted in the back of the console. Readout is exactly 100 mv for zero error and proportionately high or low depending on the deviation encountered.

The Incremeter, or "% Error" indicator, is a differential DC instrument, one side of which is fed a constant current by an internal ±.01% Zener diode reference source. By shunting or adding series resistance to the other side, the Incremeter can be made to receive a proportional signal regardless of the level of operation of the console. Thus it can be calibrated in "% Error" to indicate deviations between the setting of the console and the input to it.

Accuracy of the Zener reference is unaffected by variations in line voltage of 95 v to 135 v or changes in temperature of 20°C to 30°C. It is recommended that the reference be checked monthly although stability data compiled to the present time indicates it is capable of maintaining its output accurately for periods of one year or more. External binding posts are included for recertifying against a standard cell. Facilities are provided for a simple screw adjustment of the reference (±.2% maximum possible variation) if a modification of the output is found necessary.

* *The Incremeter is described on pages 70 to 71.*

Thermocouples are of the uncalibrated type and replacement can be made from the front of the panel. Thermocouple protection is provided on all voltage ranges for overloads of 500% or 500 v above rated input, whichever is the lesser figure.

Coarse and fine controls are provided for use with external DC power supplies and/or batteries. It is recommended that a DC constant voltage supply giving 1000 v at a 100 ma min. be employed. Ripple should be no greater than .5% max.; short term stability (1 minute or longer) should be better than .025%.

The console contains a separate DC circuit for use when only DC measurements or calibrations are required. (See Figs. 1 and 2.) Operation is as fast as it takes to dial the console to the value to be checked, set the instrument under test to the same point and read the Incremeter in "% Error."

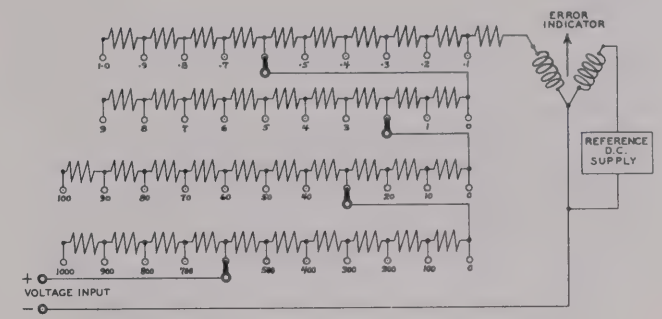


Fig. 1. Basic DC voltage measuring circuit

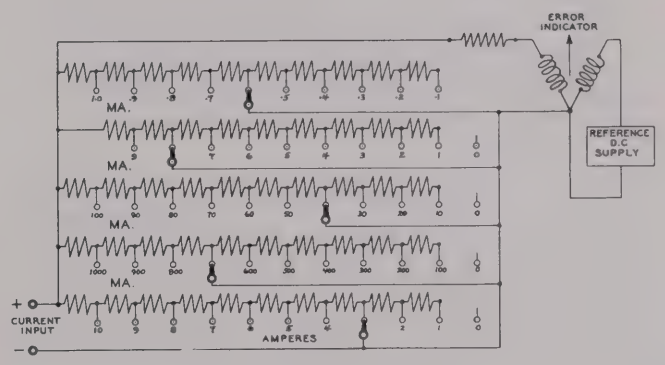


Fig. 2. Basic DC current measuring circuit

AC measurements or calibrations are made by using a thermal transfer mechanism which refers back to the console's DC circuit. The basic circuit as devised by F. L. Hermach of the National Bureau of Standards eliminates the effect of a change in the heater resistance of a thermocouple as a factor in accuracy. This is of importance since the heater resistance varies with operating temperature and therefore with increasing input. It also is subject to permanent change from relatively small overloads.

MODEL LTC-1
AC/DC AND DC CALIBRATION CONSOLE

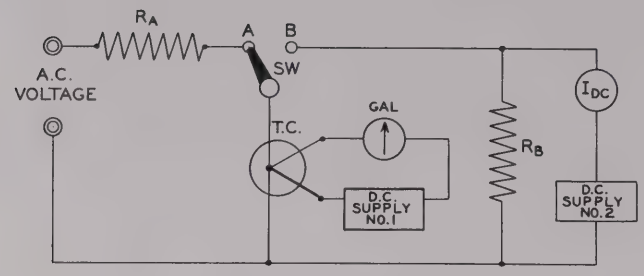


Fig. 3. Basic AC/DC voltage transfer circuit

The basic AC/DC voltage transfer circuit is shown in Fig. 3. If an AC voltage is impressed across R_a and the thermocouple heater by placing the switch in position "A", current flows through the heater and produces a DC junction output voltage. DC supply #1 can be adjusted to give a stable output exactly equal and opposite to the thermocouple output. At this point the galvanometer indicates a balanced condition. When the switch (SW) is turned to "B" and DC supply #2 is adjusted until the galvanometer returns to balance, the thermocouple output is the same as when the switch was in position "A", and hence the heater current is then identical to that which was produced by the original AC voltage.

The original heater current is $I_{tc} = \dfrac{V_{ac}}{R_a + R_{tc}}$

The second heater current is $I_{tc} = \dfrac{I_{dc}\, R_{tc}\, R_b}{R_{tc}\,(R_{tc} + R_b)}$

Equating the two values of I_{tc}, $\dfrac{V_{ac}}{R_a + R_{tc}} = \dfrac{I_{dc}\, R_{tc}\, R_b}{R_{tc}\,(R_{tc} + R_b)}$

where
- $R_a + R_b$ = Calibrated resistance
- R_{tc} = Thermocouple heater resistance
- I_{tc} = Thermocouple heater current
- V_{ac} = AC voltage

If $R_a = R_b$ the equation reduces to $V_{ac} = I_{dc}\, R_b$, which indicates that the thermocouple resistance is not a factor in accuracy when a second shunt resistance equal to R_a is placed across the thermocouple in position "B".

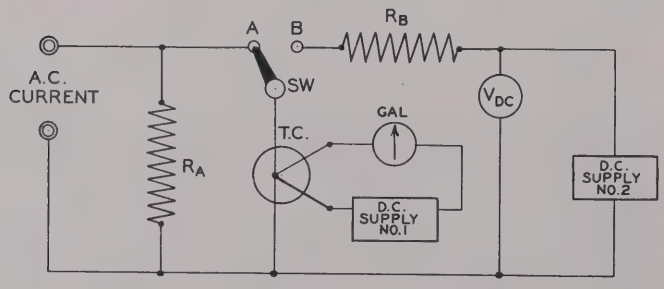


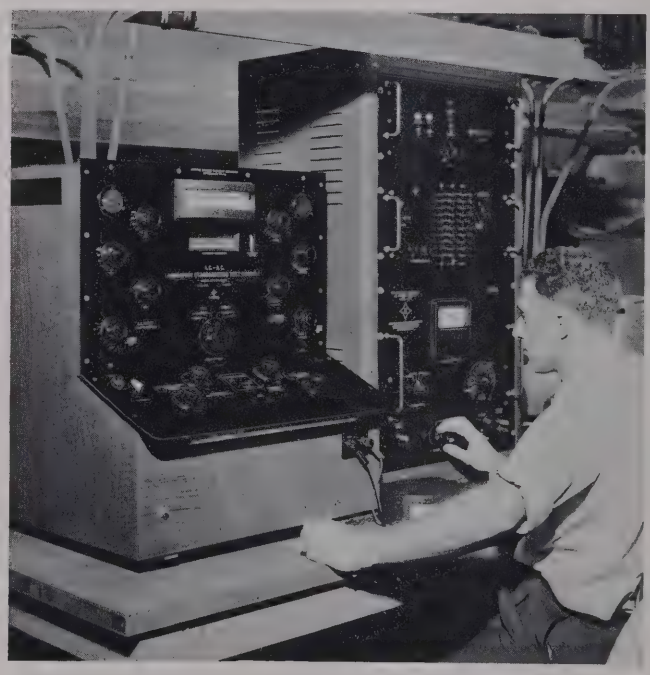
Fig. 4. Basic AC/DC current transfer circuit

In actual operation, the resistance R_a is switched into the position of R_b for the DC substitution checking. Any variation is eliminated that might exist if separate resistors were used instead of a single unit. (R_a is actually a whole series of decade resistors to provide the complete range of the console.)

A similar circuit is employed for AC current measurements as shown in Figure 4. AC current is applied through a shunt "R_a" and a thermocouple is connected directly across the shunt when the switch is at "A". The thermocouple output is balanced to zero by means of DC supply #1. The thermocouple is then switched to "B" and a DC voltage applied through a compensating resistance "R_b" to produce the same thermocouple output as evidenced by the return of the galvanometer to zero. If R_a and R_b are equal, an analysis similar to that done for the AC voltage shows that $I_{ac} = \dfrac{V_{dc}}{R_a}$, and V_{dc} can be interpreted directly in terms of the AC input current. (The shunt "R_a" is actually a series of decade resistances to provide the current range of the console.)

The operation of the AC/DC transfer circuit in the Model LTC-1 is dependent on the short term stability of the thermocouple, the AC/DC reversal of the thermocouple, the short term stability of the two DC supplies and the absolute accuracy of the resistance decades. All of these factors are carefully controlled in production, and the total accumulation of the possible errors in the console is held to better than ±.05% of reading.

Model LTC-1 Price $5560.00



"One man operation" is all that is necessary when using the Model LTCA console and LTPS power supply to calibrate an AC/DC indicating instrument up to 20 kc. The units shown are the first versions manufactured. They have been in continuous usage since 1959. Present day models have additional features that emphasize simplicity and reliability.

MODELS LTC-1 AND LTCA-1 CONSOLES
MODEL LTPS-10 AC POWER SOURCE

The Model LTCA-1 is a Hermach type test console constructed in exact accordance with the specifications for the AC/DC thermal transfer portion of the Model LTC-1 described in pages 52 to 54. It differs only in that it does not contain a separate DC measuring circuit that bypasses the thermocouple transfer system. However, it contains all of the other features of the Model LTC-1 and, when AC measurements are of primary importance it has the advantage of being lower in cost. DC measurements or calibrations can be accomplished by performing DC to DC transfers via the thermoelement.

MODEL LTCA-1

SPECIFICATIONS

Same as listed for the AC/DC transfer section of the Model LTC-1 described on pages 52 to 54. (External DC voltage supply and 6 v storage batteries not required.) All AC measuring "Optional Accessories", as listed below are equally applicable to the LTCA-1.

Model LTCA-1 **Price: $4550.00**

OPTIONAL ACCESSORIES

1. AC Power Supply: The Model LTPS-10 is an ultrastable, low distortion, variable frequency AC power source designed specifically to operate within the performance capabilities of the Models LTC-1 and LTCA-1.

MODEL LTPS-10

SPECIFICATIONS

OUTPUT RANGE	0-1100 v or 0-12 amps
RESOLUTION	Continuous
FREQUENCY RANGE	20 cps to 20 kc
OUTPUT POWER	50 va max. at any voltage or current level over the specified frequency range
HARMONIC DISTORTION	.1% max. at full 50 va level from 50 cps to 20 kc
AMPLITUDE STABILITY	Voltage: .1% for line variations from 105-125 v; .01% for 5 minutes with line voltage fixed
CABINET	Aluminum; gray; 22" w x 16" h x 17¼" d
APPROX. WEIGHT	50 lbs. net; 80 lbs. shipping

SPECIFY: Model LTPS-10 **Price: $3850.00**

2. The Model TR, Types 1 and 2, listed in Section 10, are current transformers designed for precision laboratory measurements.

3. Replacement Thermocouples: Insulated heater type vacuum thermocouples are available for field installation. Reversal is less than .01% (AC/DC error is no greater than ½ that figure, or less than .005%.) No calibration is required.

The Models LTC-1 and LTCA-1 each employ 2 separate thermocouples of different sensitivities as follows:

Model	Code	Usage	Price
LT-10M	TENTH	All voltage ranges	$48.00
LT-2M	TWOTH	All current ranges	58.00

Specify model, code and price when ordering replacement thermocouples.

4. Range Extension: Higher AC current ranges can be obtained by employing current transformers such as the Model TR. (See Item 2 under "Optional Accessories.") AC and DC voltage ranges can be extended by adding external multipliers to the 1000 v range. (When calculating the value of a multiplier, subtract the resistance of the console on its 1000 v range, which is 100,000 Ω for AC, or 100 Ω/v, and 1 megohm for DC, or 1000 Ω/v.)

Shunts with accurate potential drops across their terminals can be employed in series with higher current ranges to provide AC or DC calibration outputs down to a fraction of a millivolt. Conversely, a high resistance multiplier can be used to obtain current calibration points of higher sensitivity. Correspondence is suggested when ordering shunts or multipliers for the extension of ranges. Give overall accuracy required, and when AC ranges are to be extended, state frequency span of operation. Shunts and multipliers are described in Section 10.

MODEL FLH
AC/DC VOLTAGE TRANSFER STANDARD

SPECIFICATIONS

AC/DC PORTABLE TRANSFER STANDARD—HORIZONTAL USE

*ACCURACY AND FREQUENCY	A. **When furnished with an NBS Certificate:** .01% of reading from 20 cps to 30 kc; .02% of reading above 30 kc to 50 kc B. **When furnished with a Sensitive Research Certificate traceable to NBS:** .02% of reading from 20 cps to 30 kc; .05% of reading above 30 kc to 50 kc
TYPE	Thermocouple voltage transfer standard. True rms response
SENSITIVITY	100 ohms per volt (approx.)
READOUT	External galvanometer and panel mounted indicating instrument with a 6.1", 150 div. scale. (Both items are optional equipment.)
GALVANOMETER SENSITIVITY REQUIRED	10 Ω internal resistance; .005 μa/mm min. deflection sensitivity
RECOMMENDED GALVANOMETERS	1. **Commander Type SR4 Galvanometer** provides a deflection of 8 to 12 mm at 100% to 125% of rated voltage for a ±.01% AC/DC difference. Minimum deflection at 50% of range value is 2 mm. 2. **Commander Type 5214 Photocell Amplifier and SR21 Galvanometer** provide a minimum deflection of 100 mm for a ±.01% AC/DC difference. ***External galvanometers are offered as "Optional Accessories."***
THERMOCOUPLE REPLACEMENT	Uses uncalibrated thermoelements (See "Optional Accessories.")
SHIELDING	Electrostatic
RANGE CHANGING	Switch controlled
CASE	Formica; 21¼" x 13" x 6⅞" deep; black bakelite panel; hinged cover; carrying handle
WEIGHT	25 lbs. net; 45 lbs. shipping

*Accuracy is defined as the deviation in percent shown by the Model FLH when compared to the national AC/DC difference standard maintained by NBS. At the time of this writing it is the policy of NBS to state their own AC/DC difference measuring uncertainty as ±.01% from 20 cps to 30 kc and ±.02% above 30 kc to 50 kc. The accuracy of the Model FLH is guaranteed on this basis when an NBS Certificate is specified. The accuracy guarantee conceivably might be considerably bettered should the state of the art improve, since no deviation currently being reported for the Model FLH in NBS Certificates is greater than their stated uncertainty. In addition, since the highest volt ranges of the instrument generally have the greatest frequency influence, the lower volt ranges can be considered to have substantially better fundamental accuracy or a greatly expanded frequency range. In other words, the tolerance that now appears as the overall accuracy is a minimum figure stated for that combination of frequency range and voltage range which gives the maximum error.

Model FLH's offered with a Sensitive Research Certificate are calibrated against an NBS certified instrument. Accuracy is derated only because an additional transfer error could theoretically exist because of the interposition of another standard. A conservative approach dictates that the Sensitive Research Certificate allow for an additional ±.01% tolerance up to 30 kc and ±.03% above 30 kc to 50 kc, *even though the actual performance of the instrument is the same whether an NBS or SRIC Certificate is issued.*

The Model FLH is capable of being used at higher frequencies with little decrease in accuracy. On special request NBS can do AC/DC difference tests above 50 kc with an uncertainty of ±.03%.

OPTIONAL SPECIFICATIONS

***1. NBS Certificates available as follows:**

Frequency Range	Additional Cost
A. 20 cps to 30 kc	$140.00
B. 20 cps to 50 kc	280.00

Specify: NBS Certificate and state whether testing is to be accomplished up to 30 kc or 50 kc.

The Model FLH has been named in honor of Francis L. Hermach of the National Bureau of Standards in Washington, D.C., in recognition of his accomplishments in the field of AC/DC transfer measurements.

MODEL FLH

GENERAL DESCRIPTION

The Model FLH is a precision thermocouple transfer standard, designed to measure in percentage of reading the influence of frequencies (AC/DC differences) between 20 cps and 50 kc on the indication of voltmeters, voltage calibrators and other transfer standards over a range of 1.5 v to 1125 v. Facilities are also provided for the direct connection of external thermocouples to an internal millivolt source for AC/DC *current* transfer measurements. (See "Optional Accessories.") A Sensitive Research Certificate is normally supplied but an NBS Certificate from 20 cps to 30 kc or from 20 cps to 50 kc is available when specified.

Two versions of the Model FLH are standard. It can be supplied with an electrical indicating instrument that serves (1) as a "hunt" instrument to quickly locate the magnitude of voltage being measured, (2) to preclude overloading the thermo element and (3) to give relatively fast ±.2% accurate measurements of AC/DC difference (a convenience in those instances where higher accuracy is not necessary). The indicating instrument is similar to the Model N series of DC millivoltmeters described in Section 3. However, it is calibrated and the scale is drawn to the approximate square law characteristics of a thermocouple. Precision, rather than absolute high accuracy, is important in the instrument's application but it is guaranteed to be within ±1% on ranges above 3 v.

Galvanometers are offered separately. This allows a purchaser to use a suitable galvanometer on hand or procure one with the correct sensitivity. The FLH cannot be utilized to its full capability as a transfer standard unless the sensitivity of the galvanometer used for readout is sufficient to detect minute AC/DC differences of ±.01% or less. For this reason it is technically unsound to build in a small scale galvanometer with limited sensitivity and at the same time provide terminals for substituting an external galvanometer. Therefore, the galvanometers under "Recommended Galvanometers" in the specification table, or their equivalents, are the only ones recommended for proper operation of the Model FLH (see "Optional Accessories").

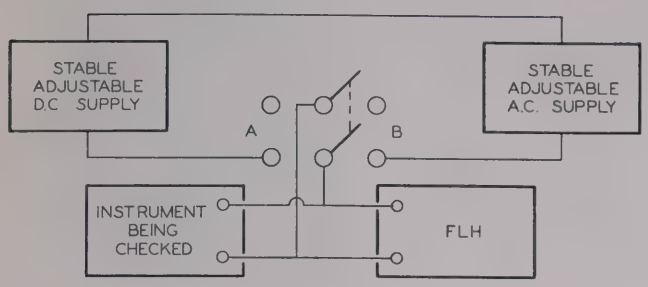


Fig. 1. To Measure AC/DC Difference

The Model FLH is ideally suited for the certification of the AC/DC differences of other transfer standards (see Fig. 1), and when used with precision DC potentiometers and their accessories, for the high accuracy measurement of AC voltages (see Fig. 2). If the proper accessory standards are employed, and NBS certified correction figures are applied for frequency response, AC measuring accuracy is comparable to that which may be obtained on DC. By using a potentiometer such as the Dauphinee Type 9144 (accuracy ±10 ppm), a volt ratio box such as the NBS Type 9700 (accuracy ±10 ppm) and saturated standard cells in a standard cell enclosure such as the Type 9152, an overall DC system accuracy of ±.003% can be achieved without difficulty.* When these standards are used with the Model FLH *it is practical to make AC measurements to an accuracy of ±.013% without the use of correction figures. When using correction figures supplied in an NBS certificate, accuracy approaching that of NBS can be achieved.*

The basic accuracy of the Model FLH is derived from the flat frequency response of its multipliers. Long term resistor stability is of no importance. If the instrument is not physically impaired, its frequency response will remain fixed for an indeterminate period of time. *Quoting directly from NBS certificates, "Based on experience with similar instruments, it is expected that the AC/DC differences will not change during the next few years by as much as 0.01% of the applied voltage between 20 cps and 20 kc and 0.02% at higher frequencies".*

A thermal element is used as the basic transfer mechanism. A millivolt source is connected in series opposition to the output of the thermal element and to the external galvanometer employed. The galvanometer is easily self-calibrated by depressing one of the keys installed on the instrument's panel to give a deliberate shift in sensitivity of .01% or .1% as desired. The magnitude of the AC/DC difference is obtained by:

1. Noting the difference in deflection of the galvanometer from AC to DC.

2. Self calibrating the galvanometer so that a given deflection is known to be proportional to either .01% or .1%. (For example: If the AC/DC difference is 20 mm divisions, and self calibration determines that the sensitivity of the galvanometer is 10 divisions for a .01% change, the AC/DC difference is .02%,

$$\text{or the AC/DC \% Difference} = \frac{.01 \times 20 \text{ mm div.}}{10 \text{ mm div.}}$$

**See "COMMANDER" instrument catalog "A Brochure of Electrical Measuring Standards", Section 11.*

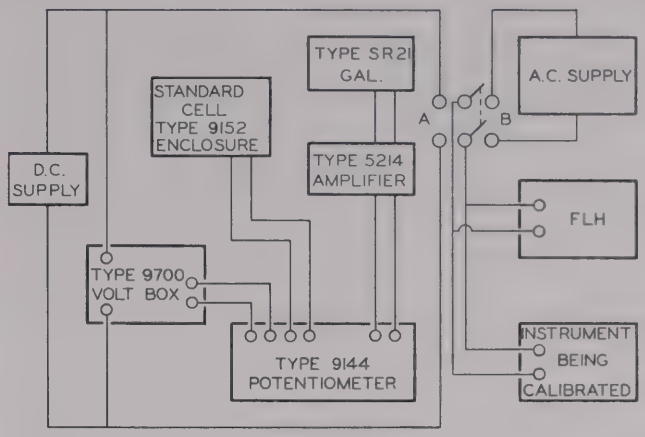


Fig. 2. To Calibrate in Absolute AC Values

In operation, the transfer unit is connected in parallel with the equipment for which an AC/DC difference is required. The instrument being calibrated is set at some reproducible point by means of a DC supply, and the millivolt source in the standard is adjusted for galvanometer balance. The combination is then switched to an AC source and the source adjusted to produce the same indication on the instrument being tested. The galvanometer of the transfer standard indicates AC/DC differences by a change from zero. The magnitude of the change is determined as previously noted. For maximum accuracy, reversed DC readings are taken and averaged. Polarity of the AC/DC difference is known because the calibration buttons always give a minus reading.

MODEL FLH

Ranges	Description	Code	Price
3/7.5/15/30/75/150/300/750 v. Ranges may be used from 50-150% of nominal value. Total measuring range is, therefore, 1.5 v to 1125 v.	Without a Model N electrical indicating instrument	FLHER	$651.00
	With a Model N electrical indicating instrument	FLHIN	751.00

See "Optional Specifications" for pricing of NBS certificates.

OPTIONAL ACCESSORIES

1. **Recommended galvanometers** are as follows:

A. *COMMANDER Type SR4 Galvanometer with 10 Ω coil. Minimum resolution at 100% of rated voltage is 10 mm divisions for a ±.01% AC/DC difference. **Price:** $277.00 F.O.B. Rouses Point, New York.

— or —

B. *COMMANDER Type 5214 Photocell Amplifier and SR21 Galvanometer. Minimum resolution at 100% of rated voltage is 100 mm divisions for a ±.01% AC/DC difference.

Price: $1088.00 F.O.B. Rouses Point, New York

2. AC/DC Current differences, in per cent of reading, can be measured by connecting external mounted vacuum thermocouples directly to the internal millivolt source and a galvanometer. Thermocouples are listed in Section 10.

3. Thermocouples for field replacement.

Specify: Model FLH-5M Code FIVETH **Price:** $60.00

MODEL PC 'POCKETPOT' MINIATURE DC POTENTIOMETER

MODEL PC

SPECIFICATIONS

PORTABLE DC POTENTIOMETER

ACCURACY	±.05% of reading or ±.5 mv, whichever is the larger figure
SENSITIVITY	Infinite resistance at null
READOUT	Direct and "in line" on (1) a switch with fifty 100 mv positions and (2) a continuously variable rheostat. The dial of the rheostat has 100 div. with a value of 1 mv/div. Each division can easily be interpolated to .5 mv.
POWER REQUIREMENT	Battery operated (Two Mallory 1.4 v #ZM9 and one Burgess 22.5 v #XXI5, or equivalents are self contained)
GALVANOMETER	Transistor amplifier and a 1½" panel instrument with external zero shifter. Sensitivity is approx. .25"/mv.
INTERNAL VOLTAGE STANDARD	.01% accurate Zener diode source
CASE	Moulded black bakelite; 9" x 4¼" x 1¾" wide
APPROX. WEIGHT	3 lbs. net; 8 lbs. shipping

GENERAL DESCRIPTION

The Model PC "PocketPot" is a .05% accurate, miniaturized DC potentiometer for use as an infinite impedance calibrator and measuring instrument. The "PocketPot" is unique because in spite of its small size it is a complete potentiometer measuring system with self-contained galvanometer and reference source. It needs no accessory equipment to perform within its measuring range. Readout is direct and "in line". Ranges are switch controlled. It is battery operated and, therefore, unlike most electrical instrumentation designed for field measurements, it does not require an AC power source. **Weight and size are such that it may easily be operated in the palm of the hand!**

Total self-contained measuring range is 0-5.100 v. "Plug-in" accessory units of the same dimensions are available to increase this range to 500 v and add ranges for current and resistance measurements from 0 to 1 ampere and .1 ohm to 9.999 megohms. (The Models PC-S Volt-Current Extension Box and PC-R Wheatstone Bridge are described under "Optional Accessories".)

The galvanometer consists of a rugged panel instrument in series with a stable transistor amplifier for good sensitivity. It is used for both precision null detection and accurate standardization of the internal reference source. Separate zero adjustments are provided for short circuit and open circuit conditions.

A ± .01% accurate Zener diode source is used as a reference for standardization. The advantages of using such a reference for a portable instrument rather than a standard cell are many. The Zener diode source is: (1) physically more rugged, (2) less susceptible to permanent damage when exposed to wide variations of ambient temperature, (3) capable of being short-circuited indefinitely without ill effect, (4) not subject to deterioration of accuracy when subjected to extreme conditions of unbalance, (5) easily re-adjusted if necessary and, (6) does not have to be completely replaced as occurs with a standard cell. The accuracy of the reference source is maintained completely independent of the exact condition of the battery, since when the battery needs to be replaced, full scale cannot be obtained on the panel indicator and the instrument cannot be standardized. It is recommended that the reference be checked monthly although stability data compiled to the present time indicates it is capable of maintaining its output accurately for periods of one year or more. Stability is warranted to be within ±.01% for 30 days. External connections are included for recertifying against a standard cell. Facilities are provided for a simple screw adjustment of the reference if necessary.

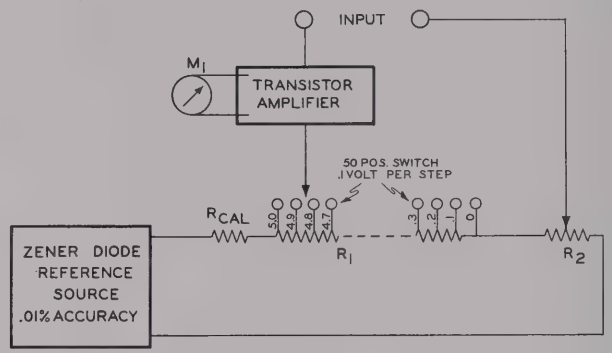


Fig. 1. Basic Circuit of Model PC "PocketPot"

The basic circuit of the "PocketPot" is shown in Fig. 1. In operation a current is standardized through resistor chains R_1 and R_2 to provide a known voltage drop which is compared on the galvanometer M_1 to an applied external voltage. The galvanometer can detect changes of ±.1 mv. The small panel instrument (also used as a galvanometer) does not have to be adjusted closer than ±1% of full scale to achieve ±.01% or better standardization. Absolute accuracy of the panel instrument is of no importance.

Operational procedures are extremely simple. The panel instrument is switched to its "Check Current" position and adjusted for full scale deflection. It is then switched to its "Read" position and becomes a null detector. "Short Circuit" and "Open Circuit" adjustments can be made for zero correction of the transistor amplifier if necessary. The galvanometer has then only to be balanced by rotating a switch and rheostat for "in line" readout of an unknown voltage.

When the "PocketPot" is used with the Model PC-S, Volt-Current Range Extension Box, overall accuracy is ±.1% of reading. When used with the Model PC-R, Wheatstone Bridge, it is employed only as a galvanometer and accuracy is, therefore, that of the bridge alone.

Model PC **Range: 0-5.100 v.** **Price $390.00**

OPTIONAL ACCESSORIES

1. Model PC-S, "Plug-in" Volt-Current Range Extension Box, is a combination shunt and volt ratio box to extend the total measuring range of a PocketPot. The mechanical connections between the two units also serve to complete the electrical circuitry. No other accessory equipment is required for operation within their measuring range. Ranges are switch controlled and convenient to use because their values can be read directly on a PocketPot by only arbitrarily fixing a decimal point. The basic circuit is shown in Fig. 2.

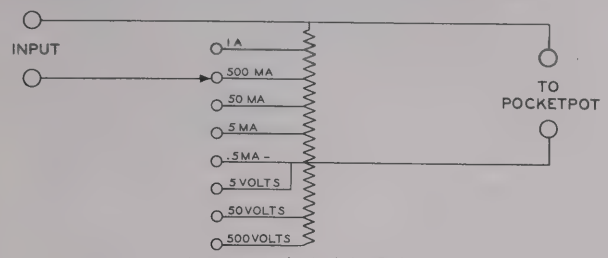


Fig. 2. Basic circuit of Model PC-S

Operation is simple! The Range Extension Unit is switched to its proper range and the PocketPot switch and slidewire are adjusted from zero to maximum value for balance on the galvanometer.

SPECIFICATIONS

ACCURACY	±.05% of reading
RANGES	.5 / 5 / 50 / 500 ma; 1 amp*; 5/50/500 v
SENSITIVITY	All current ranges 5 v drop, excepting 1 amp range 1 v drop. All volt ranges 2000 Ω/v
RANGE CHANGING	Switch controlled
CASE	Case size, weight and construction same as PocketPot

**Note 1: The 1 ampere range may be used on a limited duty cycle to measure currents up to 5 amperes by switching the PocketPot for an equivalent volt drop.*

Volt-Current Range Extension Box

Specify: Model PC-S **Price:** $175.00

2. Model PC-R, "Plug-in" wide range portable Wheatstone Bridge adds the capability of making resistance measurements to a PocketPot. The mechanical connections between the two units also serve to complete the electrical circuitry. No other accessory equipment is required. In operation the decade and multiplier dials of the bridge are set at the estimated unknown resistance value. Two push buttons, coarse and fine, are depressed as the dials are varied to obtain a "null" on the galvanometer of a PocketPot. The sum of the readings of the decade switches, multiplied by the range factor switch reading, is equal to the unknown resistance. The PocketPot is used as a galvanometer and its accuracy is not a factor in the accuracy of the bridge.

When the range factor switch of the bridge is set in its "Decade Box" position it becomes a standard resistance box.

ADDITIONAL SPECIFICATIONS

Measuring Range	Limit of Error
.1 ohm to 10 ohms	±1%
Above 10 ohms to 1 megohm	±.2%
Above 1 megohm to 9.999 megohms	±2%

Readout: 0 to 9.999 megohms on 4 dials with a value of 9 (1000 x 100 x 10 x 1)

Range Factors: x .001/ x .01/ x .1/ x 1/ x 10/ x 100/ x 1000

Decade Box Operation:

Decade Range	Max. Current
1000 to 10000 ohms	20 ma
100 to 1000 ohms	50 ma
10 to 100 ohms	150 ma
1 to 10 ohms	500 ma

Case: Size, weight and construction same as PocketPot

Wheatstone Bridge

Specify: Model PC-R **Price:** $283.00

3. A leather case is available with carrying strap and room for a PocketPot and "plug-in" accessory measuring unit. **Specify:** PocketPot Leather Case **Price** $30.00

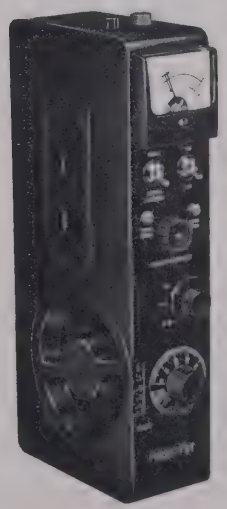
MODEL PCM

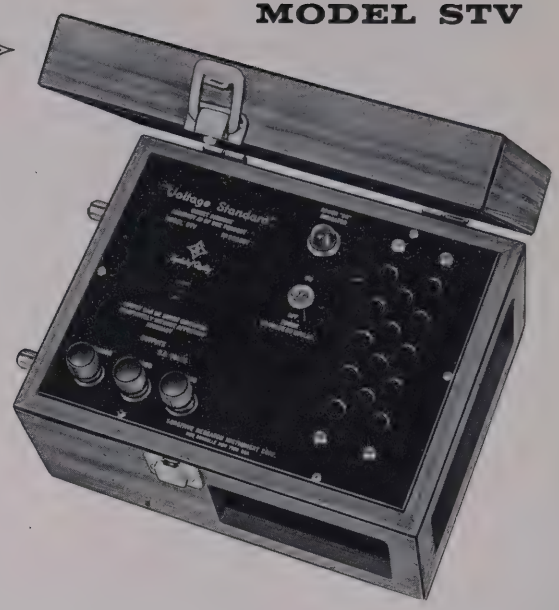
The Model PCM Multirange "PocketPot" is a miniature DC potentiometer similar to the Model PC described on page 58. It differs in that it offers increased accuracy and resolution at lower levels of voltage by the addition of two ranges of higher sensitivity. Galvanometer sensitivity is amplified threefold. Specifications are the same as for the Model PC excepting as follows:

Range Factor	Measuring Range	Resolution (Continuous)	Accuracy
×1	0-5.100 v	1 mv/div.	±.05% of reading or .5 mv (whichever is the larger figure)
×.1	0-.5100 v	.1 mv/div.	±.05% of reading or .1 mv (whichever is the larger figure)
×.01	0-.05100 v	.01 mv/div.	±.1 mv

The Model PCM can be employed with accessory "plug-in" units such as the Model PC-S Volt-Current Range Extension Box and the Model PC-R Wheatstone Bridge. Current and voltage measurements can be made on the Model PCM and PC-S with greater accuracy and precision at lower levels than with a single range instrument. Leather carrying case available. (See "Optional Accessories" above.)

Specify: Model PCM **Price: $475.00**





SPECIFICATIONS

PORTABLE DC VOLTAGE STANDARD

*ACCURACY	.01% of nominal output
*STABILITY	.01% of actual output
INPUT	100 to 130 v AC, 60 cps, (25 va)
NOMINAL OUTPUT	1.0000 v and 1.0185 v DC
TYPE	Zener diode stabilized source
LINE VOLTAGE STABILITY	.002% of actual output for 100 to 130 v input
TEMPERATURE COEFFICIENT	Less than ±.001% per °C from 20°C to 30°C. (Accuracy is reduced when operation is outside these limits, but output is reproducible within the normal precision of the instrument.)
OPERATIONAL LIFE	25,000 hours minimum
CASE	Formica; 9⅜" x 7⅝" x 5" h; black bakelite panel; hinged cover; carrying handle
WEIGHT	10 lbs. net; 24 lbs. shipping

*The nominal outputs of 1.0000 v and 1.0185 v are engraved on the instrument's panel. The actual outputs are measured and adjusted to be well within ±.01% of these values. Stability is guaranteed to be better than ±.01% of the actual outputs.

OPTIONAL SPECIFICATIONS

1. Special single or multirange instruments can be furnished with nominal outputs up to 7.5 v.

2. Special battery powered instruments available.

3. Special units are available for use as standard current sources into specific external resistances.

GENERAL DESCRIPTION

The Model STV is an extremely accurate and stable DC voltage source for use as a reference standard with "null balance" devices such as potentiometers and other infinite impedance comparators. It is equivalent in accuracy to the best unsaturated standard cells and superior in almost all other respects to both saturated and unsaturated types. Accuracy and stability are unaffected by vibration from transportation, exposure to extremes of temperature, short circuiting or operating position. The Model STV is unique in that rated accuracy and stability are achieved without housing it in a constant temperature bath and cost is, therefore, reduced to less than one-half that of similar instrumentation with equivalent specifications.

While the stability of the Model STV is guaranteed to ±.01% of actual output, performance figures obtained to date indicate units are capable of stabilities of ±.005% for periods in excess of a year. However, so that the voltage standard may be used with great assurance to its best accuracy, a 30-day recertification period is recommended. As a convenience, the instrument is furnished with a screwdriver adjustment so that its output may be varied if desired. The nominal output values can be readjusted by the user to 10 ppm or better.

Short term stability of the Model STV, after a sufficient warm-up period, (see Fig. 1), can be relied on to a few ppm or better. If frequently referenced against a saturated standard cell, it can be employed to great advantage as a working standard with considerably higher accuracy than normally guaranteed. The use of the Model STV as a working standard lessens the chances of damaging or disturbing saturated cells from unbalanced electrical circuits and excessive handling. If shorter recertification periods than the recommended 30 days are adopted, higher accuracy guarantees can be made based on a history of each individual instrument. The reader is referred to Section 11 for a description of the COMMANDER Type 9152 series of Constant Temperature Enclosures with up to 12 Saturated Standard Cells.

TYPICAL CURVE SHOWING VOLTAGE VARIATION WITH TIME

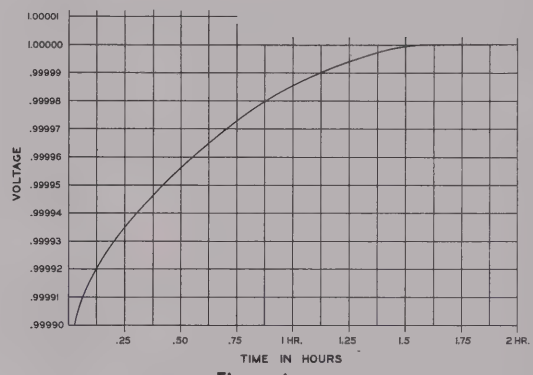


Figure 1

While the Model STV is essentially a zero current drain source, it can be operated into any impedance without damage. It can be short circuited indefinitely without affecting accuracy or life expectancy, and instantaneously regains its original open circuit voltage when the short is removed. For calculating output current, the Model STV may be considered a perfect voltage source in series with a 2000 ohm resistance; thus its maximum current output when short circuited is .5 ma.

The Model STV is furnished with a Sensitive Research Certificate giving the measured value of both outputs. Calibration is accomplished by continuous reference, for a period of 30 days, to a bank of NBS certified saturated standard cells. Calibration accuracy is better than 5 ppm.

Model STV **Type 1A** **Price: $280.00**

PANEL MOUNTED INSTRUMENTS

The Model STV can be furnished on a 19" × 5¼" × 5/16" black bakelite panel for rack mounting.
Specify: Model STV, Type 1B. **Price:** $295.00

LABORATORY STANDARD ELECTRICAL INDICATING SYSTEMS

ABOUT LABORATORY STANDARDS

"Laboratory Standards" comprise a group of AC, DC or AC/DC electrical measuring instruments characterized by an accuracy of .1% of full scale and a 12" scale length. Detailed here are certain construction features they have in common that are worthy of consideration along with an examination of their individual performance specifications. The design end of any Laboratory Standard is "accuracy and reliability—without compromise!"

While the basic circuits of all electrical indicating instruments of the same type empirically resemble each other, their construction details can vary significantly. The components used in Laboratory Standards are individually selected to provide and maintain the precision and reliability of a .1% accurate instrument. Diamond pivots, with a .0009" riding surface, and spring mounted sapphire jewels are employed to give a virtually friction free moving coil system. The jewels are adjusted to firmly support the weight of the moving system under static conditions, but to depress instantly without damage to the bearings in the event of shock or vibration. The moving element is wound as a self-supporting coil with a continuous layer of bonding agent. The absence of a metal coil former enables a lighter weight coil with significantly more turns for a given air gap. Circuits are calculated to employ unusually strong restoring springs that are stressed well below their elastic limit at the maximum deflection of the instrument so as to make any zero shift almost imperceptible after prolonged operation. The combination of low coil mass and strong restoring springs results in an excellent torque to weight ratio. The double pivoted moving system rotates smoothly in a strain free mounting that is designed to take up equilibrium positions with certainty and without interference. Prior to calibration the instrument is heat cycled and deflected "on and off" for a period of 3 months. This combination of meticulous assembly and selected components produces an indicating mechanism of the highest precision and stability.

The resolution of Laboratory Standards is enhanced by the addition of vernier subdivisions. Scale plates of heavy brass are fastened to eight ½" diameter uprights that in turn are mounted on a 7/16" thick flat bakelite slab—all to provide the maximum dimensional stability.

Laboratory Standards are furnished with adjustable leveling feet, an internal thermometer and a bubble level mounted on their panels to indicate the ambient temperature and reference plane in which they were calibrated. They contain glass windows with a grounded, clear conductive undercoating to prevent the surface accumulation of electrostatic charges.

Manganin resistors are well aged before and after installation in the instrument. A continuous history of resistor stability is compiled during manufacture.

Listed with Laboratory Standards are certain electrical indicating instruments which because of their application fit into this category even though they lack features such as a bubble level, leveling feet and a thermometer. They have 6.3" scale lengths and relatively high accuracies for their intended use. Their application as standards makes their inclusion more fitting in this section than elsewhere in the catalog.

AC/DC 'SELF CHECKING' VOLT-AMP-MILLIAMMETER

SPECIFICATIONS
AC/DC PORTABLE—HORIZONTAL USE

MODEL THACH COMB. 5X

*ACCURACY	.1% of full scale at Self Check points; .2% of full scale at all other points
*FREQUENCY	DC and 7 cps to 4 kc excepting ranges of 2 amps, 5 amps and 1000 v have an upper limit of 2.5 kc
TYPE	Thermocouple; permanent magnet, double pivoted moving coil system; internal "Self Checking" system; true rms response
SENSITIVITY	100 Ω/v. Resistance of current ranges listed in table on page 63
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	Two scales, one for each thermocouple; 100 div. printed 0-50/100/200
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
†SHIELDING	Electrostatic
RANGE CHANGING	Switch controlled excepting the 2 amp, 5 amp and 1000 v ranges on separate binding posts
SELF CHECKING SYSTEM	Unsaturated standard cell and galvanometer in Combs. 1X and 3X; Zener diode regulated voltage source in Comb. 5X
POWER REQUIREMENTS	Combs. 1X and 3X use internal replaceable batteries (Mallory Mercury RM-42R or equivalent). Comb. 5X uses external 115 v 60 cps line source

*See notes *† top of page 62.*

TEMPERATURE COEF.	Compensated from 20°C to 30°C
OVERLOAD RATING	1000% manually operated thermocouple overload protection system. 5000% automatic overload protection on special order. See "Optional Specifications."
MECHANICAL ZERO	External zero shifter
REPLACEMENT THERMOCOUPLE	Available only at time of ordering instrument. (See "Optional Accessories.")
CASE	Formica; 20¼" x 10¼" x 8" h; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	33 lbs. net; 90 lbs. shipping

*Accuracy stated includes AC/DC differences over the entire frequency span. However, since the highest current and voltage ranges have the greatest frequency influence, in practical usage the lower ranges can be employed to wider frequency limits with no depreciation in accuracy. Accuracy is never less than 1% up to 15 kc, excepting on the 2 amp, 5 amp and 1000 v ranges where the upper frequency limit is 10 kc. In such areas, regardless of absolute accuracy, if the instrument is not physically impaired its frequency response can be expected to remain virtually fixed. Specifically, it is not expected to change by as much as .02% in a period of a few years. Therefore, once an AC/DC difference for any range is established at a particular frequency, the instrument can be expected to repeat its readings at that frequency to well within its guaranteed precision. The effect of frequency on a given full scale range remains the same regardless of the input level, i.e. when operation is on the 10 v range AC/DC differences are the same whether the instrument is indicating 10 v or some lower value. Therefore, it follows that the instrument can be "Self Checked" or calibrated from an external source on DC, and redeterminations of frequency response can be made relatively infrequently.

†No magnetic shielding is necessary since the instrument can be "Self Checked" and standardized under the operating conditions encountered in each measurement. Accuracy, therefore, is unaffected by nearby magnetic fields.

OPTIONAL SPECIFICATIONS

1. All Combs. of the Model THACH can be furnished modified for use with the Model THACH-PS, a special AC/DC regulated source designed to furnish the power required to use the Model THACH as a calibrator and to reduce the danger of overloading both the standard and/or the instrument under test. *The Model THACH can be constructed with provision for interlocking controls with the Model THACH-PS at an additional cost of* **$100.00.** The power supply can then be added at any future date without a surcharge. *If this modification has to be made to an existing Model THACH the additional cost is* **$200.00.** The Model THACH-PS power supply, is described more fully under "Optional Accessories."

2. 5000% automatic thermocouple overload protection can be provided instead of the 1000% manual protection system normally supplied. The automatic system protects the thermocouple continuously during operation. The manual system contains a "Push to Read" button which protects the thermocouple when the instrument is initially inserted into a circuit. Once the correct full scale range to be used is ascertained the manual overload protection system must be taken out of the measurement circuit. (See text describing the manual thermocouple protection system.)

The automatic overload system is connected internally directly to the heater wires of the thermoelement. When the heater current exceeds a preset value, a short is applied across it which allows a current flow of 500 ma. Simultaneously a red warning light is lit up on the panel of the Model THACH. The short and the lamp remain on until a reset button is pressed that returns the circuit to normal again.

The insertion of the automatic thermocouple protection system does not affect the frequency response of the instrument when operation is up to 7.5 kc; at 10 kc frequency influence is approximately .1%, at 20 kc approximately .5%. It serves as protection only for the thermoelement. In terms of total instrument protection it safeguards the Model THACH for overloads of 5000%, or 10 amps and 500 v above voltage range rating, whichever is the lesser figure. As a special feature, provision for attachment of an external alarm system can be supplied at an additional cost of **$25.00.** (Correspondence is required.)

The protection system utilizes 2 internal replaceable batteries, Burgess Types XX15, 22.5 v and HG502 mercury cell, 1.4 v, or equivalents. Battery life is approximately 1 year if on standby only, and 50 hours if the instrument is left continuously in an overload condition.

Specify: Automatic Overload Protection
Price: $125.00 additional

GENERAL DESCRIPTION

This distinguished "Self Checking" AC/DC Volt-Amp-Milliammeter has earned world wide praise and popularity since its introduction in 1954. *The Model THACH is versatile, accurate, reliable, easy to operate and relatively low in cost!* There is no other self-contained portable electrical indicating instrument that can boast of all its advantages! Consider the following features and performance specifications!

- **±.1% accuracy at self check points and ±.2% at all other points on AC and DC over the full measuring range and frequency span.**
- **Self Checking! The Combs. 1X and 3X incorporate a standard cell and high sensitivity galvanometer. The Comb. 5X references a Zener diode regulated voltage source. Internal adjustment can be made to compensate if necessary for small changes in sensitivity due to temperature, nearby magnetic fields and other operating conditions.**
- **Application as a wide range AC/DC measuring instrument, transfer standard and instrument calibrator.**
- **19 overlapping full scale ranges of AC/DC current and voltage. Operation is almost always at or near full scale for maximum accuracy. Scale divisions are greatly expanded in this upper area enabling maximum resolution.**
- **Convenient to use—simplified operation. Self Checking is a matter of less than a half minute's time before a measurement. Confidence is a convenience—when in doubt "Self Check." Usage is then like any other indicating instrument, connect and read directly. Ranges are switch controlled to 500 v and 1 amp. The glass window has a clear conductive undercoating permanently installed to prevent static charges from accumulating on its surface.**
- **True rms response regardless of wave form.**
- **Thermocouple overload protection either manually operated or automatic.**
- **Two thermocouples with independent circuits and separate scales.**
- **Readily applicable to field or laboratory conditions. Diamond pivoted with sapphire shock mounted jewels to give friction-free performance. Cases are made of tough durable formica and gasketed to provide an effective dust and humidity barrier.**

The Model THACH is available in three combinations all of which have the same full scale ranges and general performance specifications, but which vary in the design of their Self Checking circuits. The Comb. 1X utilizes a pair of mercury batteries and rheostats by means of which a DC current can be supplied to either of two thermocouples and also through a monitor resistance. Across the monitor resistance is a standard cell and a galvanometer. Recertification of the instrument is accomplished by adjusting current from the supply to that point at which the drop across the monitor resistance exactly equals the voltage of the standard cell (as indicated by a zero deflection on the galvanometer).

AC/DC 'SELF CHECKING' VOLT-AMP-MILLIAMMETER

If the indication of the instrument is not at full scale after self checking, a "micro control" rheostat on the DC millivoltmeter side of the instrument can be used to make a corrective adjustment. This procedure effectively serves to recalibrate the Model THACH in terms of its standard cell at the time of its use. In the Comb. 1X full scale deflection only can be self checked.

The Comb. 3X employs much the same autocalibration system with one major modification, self checking can be accomplished via a series of push buttons at the 90%, 80%, 70% and 60% scale points as well as the 100% or full scale point. (Note: The first Model THACH's with multi-self checking capability standardized at points every 20% on the scale, or every other cardinal point. While such a distribution is available at no extra charge if specified, the present day system appears to give greater benefits. Standardization is now on the upper two thirds of the physical scale length where good instrumentation practice demands all measurements should be made. In addition, adjustment at the 60% point almost assures the lower end of the scale being accurate.)

The Comb. 5X speeds up and simplifies still further the self checking procedure. Like the Comb. 3X the instrument can be self checked on the upper 5 cardinal points on its scale by merely depressing the proper push button. However, in place of the internal battery source to supply a DC current, which is standardized by means of a galvanometer and standard cell, a special solid state power supply is substituted. This supply is similar to the Model STV described separately on page 60. The entire self checking procedure involves only switching to a "Check" position and adjusting the full scale deflection of the instrument by means of a rheostat. A 60 cps 115 v external source is required for operation.

The Comb. 5X was originally developed for use by the USAF. By eliminating the standard cell and galvanometer as component parts and substituting a Zener diode voltage reference in its place, the Comb. 5X was made considerably less susceptible to possible damage from abnormal handling, vibration and storage at wide limits of temperature.

A manually operated "Push-to-Read" thermocouple overload protection system is normally self contained in all combinations. The instrument has a red "Safety" line drawn and labeled at the 20% point on its scale. When the push button is left in an upright position, 80% of the input current is shunted around the heater of the thermoelement. If the instrument's indication is below the "Safety" line, it is being used on the correct full scale range; if above the line an overload is being applied and change to a higher range value is indicated. The button can be turned to lock in place in the "Read" position. This removes the safety shunt for normal operation while making measurements. The overload system is compensated so loading of the circuit being measured remains at the same level whether the button is depressed or not. The thermocouple is protected for overloads of 1000%. Overall instrument protection (including range resistors) is 1000% or 10 amps and 500 v above rated voltage, whichever is the lesser figure.

An automatic protection system is available that safeguards the thermocouple against overloads of 5000% *at all times*. It is described more fully under "Optional Specifications."

RANGES

Voltage:	1	2	5	10	20	50	100	200	500	1000v AC/DC
Sensitivity:	100 Ω/v									

Current:	10	20	50	100	200	500 ma	1	2	5 amps AC/DC
Approx. Resist.:	30	37.5	20.4	11.1	5.8	2.4	1.2	.5	.24 Ω

Comb.	Code	Description	Model THACH Price	Model THACH & THACH-PS * Price
1X	DELABACHEK	Self Checking at full scale. Internal standard cell and galvanometer	$1075.00	$2170.00
3X	DEMULTILAB	Self Checking at 60%, 70%, 80%, 90% and 100% of full scale. Internal standard cell and galvanometer	1375.00	2470.00
5X	DEMULTISTV	Self Checking at 60%, 70%, 80%, 90% and 100% of full scale. Internal Zener diode reference source	1525.00	2620.00

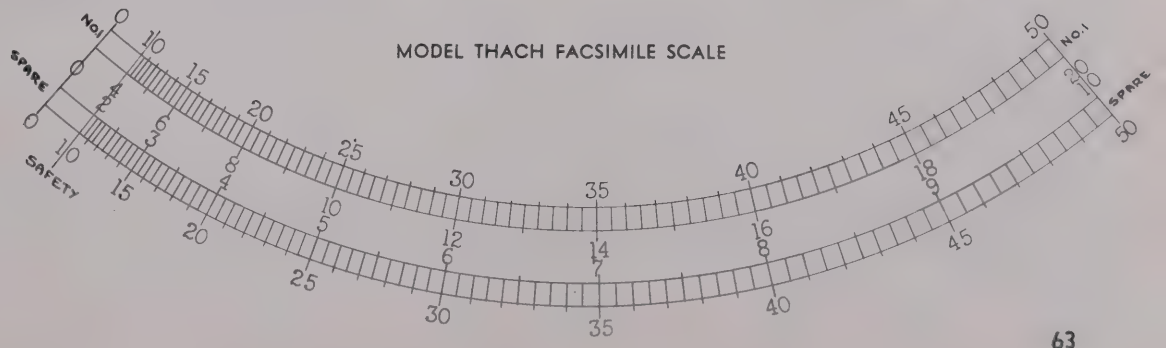
MODEL THACH

COMB. 3X

Note: If automatic thermocouple overload protection is desired add $125.00 to above prices.

*When ordered together.

MODEL THACH FACSIMILE SCALE



MODEL THACH-PS POWER SUPPLY

OPTIONAL ACCESSORIES

1. Model THACH-PS: The Model THACH is offered in combination with a general purpose power supply for use as a convenient wide range instrument calibrator. The power supply, Model THACH-PS, is a regulated source that has its controls interlocked with the Model THACH. Power to the THACH is automatically shut off when ranges are switched, reducing the danger of accidentally overloading the calibrator and/or the instrument under test. Output covers the full range of the THACH for DC and 60 cps. A special 400 cps source can be provided within the THACH-PS for 400 cps calibrations. 50-2500 cps can be plugged in for operation over a broader frequency range. Resolution of the power supply controls is better than .05% for any current and voltage range. Any Model THACH when modified (see "Optional Specifications") is available for operation with the power supply. In addition, existing instruments in the field can be modernized for this same purpose at a small surcharge.

The Model THACH-PS, while designed primarily for operation with the Model THACH, can be used independently as an excellent general purpose switch controlled laboratory supply.

OUTPUT: DC or AC (60 cps normal; 50-2500 cps depending on input). Voltage: Delivers 0-120% at full load and a max. of 0-175% at no load. 1/2/5 v. at 300 ma.; 10/20/50 v. at 100 ma.; 100/200/500/1000 v. at 25 ma. Current: 0-5 amps. at 15 watts max. on low power, or 75 watts max. on high power.

INPUT: 90-135 v, 60 cps single phase, or 115 v, 50-2500 cps from a regulated source. Approx. 200 va max. required.

WAVEFORM: 60 cps distortion 2.5% total harmonic content plus line distortion. (True rms instruments such as dynamometer, electrostatic, moving iron and thermocouple types are unaffected by wave form distortion.)

RIPPLE: Varies from .5% at full voltage and low currents to a maximum of 2.5% for currents of 1 amp or less. At currents above 1 amp ripple can always be 3% or less if series resistance is sufficient in the external circuit. It is no worse than 7% for any possible operation.

RESOLUTION: .05% or better by means of coarse, medium and fine controls

Case: Formica; 12¾" x 17" x 9" deep; black bakelite panel

WEIGHT: 59 lbs. net; 137 lbs. shipping

Specify: Model THACH-PS Code THAPOS

Price: $1095.00

2. 400 Cycle Adaptor for Model THACH-PS: The 400 cycle adaptor enables the Model THACH-PS to be used on AC for both 60 cps and 400 cps calibrations. Provision is made for its installation in all Model THACH-PS supplies. A 400 cps output switch position is incorporated on its panel and terminals are brought out inside the case to wire the 400 cps sine wave output from the frequency converter in the adaptor. The adaptor can also be furnished for field installation in the Model THACH-PS.

Specify: 400 Cycle Adaptor for Model THACH-PS

Price: $500.00

MODEL THACH-PS

3. Calibrated low reversal thermoelements cannot be supplied for field installations unless ordered at the same time as the Model THACH or when the instrument is at Sensitive Research for repair or recalibration. *Calibrated replacement thermocouples are supplied with adjusted heater and junction resistances for use at full accuracy without correction curves.*

Specify: Model TH-10M **Price:** $100.00

Uncalibrated units can be furnished with sensitivity that can be adjusted for full scale output on the instrument. However, unless the scales are redrawn the instrument might have to be used with correction charts. (The Model SCAMA, a precision scale drawing machine is described in Section 9.) Adjustment for the exact heater wire resistance which constitutes the multiplier for the lowest volt range, also has to be made. Uncalibrated thermocouples for the Model THACH are supplied with trimming resistors for heater or junction resistance adjustments.

Specify: Uncalibrated Model THACH Replacement Thermocouple.

Price: $45.00 (State serial number of Model THACH when ordering.)

4. Unsaturated Standard Cells with standard resistors can be supplied mounted for field installation in the Model THACH Combs. 1X or 3X.

Specify: Model STC, Code ACSTEL **Price:** $45.00

5. Voltage ranges can be extended by the addition of multipliers. If ordered with the Model THACH, they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. If ordered at a future date, overall accuracy is the sum of the accuracies of both units. When ordering, specify frequency at which measurements are to be made.

Shunts cannot be provided for the extension of AC current ranges since their addition can cause variations in scale linearity. *Higher AC current ranges can be achieved by employing the Model TR Transformer* in conjunction with instrument ranges of 2 or 5 amps. Accessory measuring units such as multipliers and transformers are described in Section 10.

MODEL BS-1

DC 'SELF CHECKING' VOLT-AMP-MILLIAMMETER

SPECIFICATIONS

DC LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.05% of full scale at all cardinal points; ±.1% linearity between cardinal points
TYPE	Permanent magnet, double pivoted moving coil; internal "Self Checking" system
SENSITIVITY	1000 Ω/v; resistance of current ranges listed below
SCALE	Vernier; hand-drawn; 12"; anti-parallax mirror
SCALE DIVISIONS	150 div. printed 0-15/30/75
POINTER	Knife edge
PERIOD	2 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic; unaffected by magnetic fields
RANGE CHANGING	Switch controlled except .3, 750, 1500 v and 7.5, 15 amp ranges on binding posts
SELF CHECKING SYSTEM	Unsaturated standard cell and galvanometer
POWER REQUIREMENTS	Internal replaceable battery (Mallory No. RM-12R or equivalent)
TEMPERATURE COEFFICIENT	Compensated from 20°C to 30°C
MECHANICAL ZERO	External zero shifter
CASE	Walnut; 24" x 14" x 8" h; black bakelite panel; walnut dust cover
APPROX. WEIGHT	44 lbs. net; 115 lbs. shipping

OPTIONAL SPECIFICATIONS

1. The Model BS, a previous version of the Model BS-1, offered a 300 mv range with an accuracy of .1% of full scale. Since this is a difficult and necessarily expensive range to include, it is now available only on special order. The price of the Model BS-1 is reduced a proportionate amount to reflect this change in specifications. **Specify:** Model BS-1 with 300 mv range. **Price:** $1825.00

GENERAL DESCRIPTION

The Model BS-1 is a .05% accurate, "Self Checking" DC Laboratory Standard, with 24 full scale current and voltage ranges from 750 mv to 1500 v and 1.5 ma to 15 amps. It has wide application as a direct reading instrument for making precision DC measurements and for the calibration of other instruments. It incorporates a potentiometer system that enables the instrument to *"Self Check" its own accuracy against an internal unsaturated standard cell,* and to make compensating changes if necessary to adjust to immediate measuring conditions.

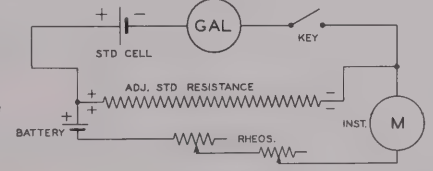
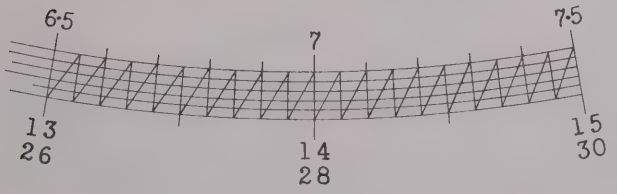
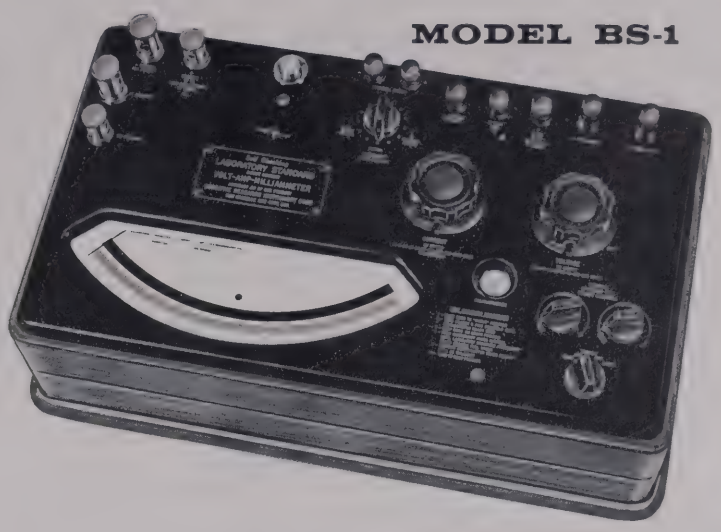


Fig. 1. Basic "Self Checking" Circuit



Section of a Facsimile Model BS-1 Scale



Accuracy of .05% of full scale on all cardinal points allows a recommended 5 to 1 ratio for the calibration of .25% reference standards and a robust 10 to 1 or more for the calibration of .5% and 1% portables. Ranges are overlapping so that most readings on the Model BS-1 can be taken at or near full scale for maximum accuracy. It can be used with equal facility and accuracy to calibrate AC/DC instruments on reversed DC.

The internal "Self Checking" circuit is similar to that of any external potentiometer system, but is for the specific measurement of the basic sensitivity of the instrument at full scale (see Fig. 1.). It is convenient to have such a system available. "Self Checking" involves but a few seconds to change a switch, which deflects the pointer of the instrument up scale, and to adjust coarse and fine controls to balance the galvanometer and place the pointer exactly at the full scale point. Such effects as occur from temperature, external surrounding magnetic fields, balance, changes in magnet strength and springs from improper usage, are virtually eliminated as accuracy factors. Long term reliability and accuracy are dependent only on the stability of the well aged manganin resistors, the linearity of the diamond pivoted moving coil system and the stability of the standard cell.

OPTIONAL ACCESSORIES

1. Ranges can be extended by the addition of external shunts and multipliers. See Section 10.

2. Replacement mounted unsaturated standard cells with standard resistors are available.
Specify: Model STC. Code DCSTCEL. **Price:** $50.00

RANGES

DC Voltage:	.75	1.5	3	7.5	15	30	75	150	300	750	1500 v
Approx. Sens.:	1000 Ω/v										
DC Current:	1.5	3	7.5	15	30	75	150	300	750 ma		
Approx. Resist.:	258	230	117	62.5	32.3	13.2	6.63	3.33	1.33 Ω		

DC Current:	1.5	3	7.5	15 amps
Approx. Resistance:	.67	.34	.14	.07 Ω

Model BS-1 Code SELFAM Price: $1750.00

MODEL B
DC LABORATORY STANDARD

SPECIFICATIONS

DC LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.1% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Vernier; hand-drawn; 12"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled, excepting multirange ammeters all ranges on binding posts
MECHANICAL ZERO	External zero shifter
CASE	Walnut; 16½" x 14½" x 3" h; black bakelite panel
APPROX. WEIGHT	17 lbs. net; 42 lbs. shipping

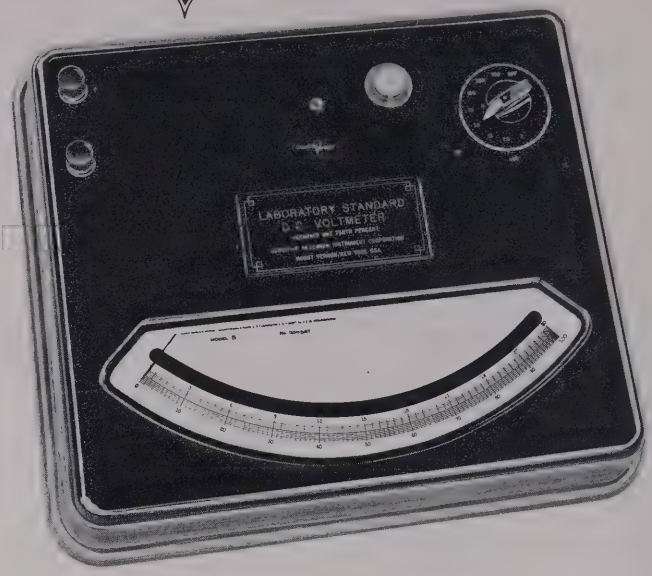
All instruments are provided with data listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. Instruments with special scales and/or ranges available. Correspondence required.

GENERAL DESCRIPTION

The Model B is a .1% accurate DC laboratory standard similar in construction to the Model BS-1 described on page 65, but without the "Self Checking" feature. Self contained single range and multirange current or voltage measuring instruments are listed covering an area from 50 mv to 1000 v and 30 μa to 1.5 amps. Ammeters with a separate external shunt box are offered with current ranges up to 50 amps. Higher current ranges can be obtained by the addition of external shunts to the millivoltmeters. Voltmeter ranges can be extended by the addition of external multipliers. When shunts and multipliers are ordered with the Model B, they are calibrated together and overall accuracy is guaranteed within the tolerance of the instrument. Laboratory standard shunts and multipliers are described in Section 10.



MILLIVOLTMETERS

Range	Scale Div.	Code	Price
50	100	BAMVLT	$650.00
100	100	BAMVOK	650.00
50/100	100	BAMVPS	750.00

Millivoltmeters are specially temperature compensated for use from 20°C to 30°C. Sensitivity is approximately 100 Ω/v. They are calibrated and supplied with a pair of .026 Ω leads. Calibration can be at the instrument's terminals if specified.

Millivoltmeters are normally supplied with 100 division scales calibrated and printed in millivolts. However, at no extra charge, if specified, they can be furnished with up to 150 division scales and/or the legend "Amperes." A 100/150 division scale, or any other double scale not exceeding 150 divisions, can be drawn at a **$42.00** surcharge. A single row of numerals is normally printed for each scale drawn. Additional rows of numerals can be printed at **$10.00** a set. A maximum of 5 rows of numerals can be provided on a scale plate.

MICROAMMETERS

Range	Scale Div.	Code	Price
*30	150	BAMICO	$725.00
50	100	BAMICH	610.00
100	100	BAMICY	590.00

Any single range microammeter from 150 μa full scale. Price **$575.00**

VOLTMETERS

Range	Scale Div.	Code	Price
3/7.5/15/30/75/150/300	150	BAVOST	$800.00
3/7.5/15/30/75/150/300/750	150	BAVOKI	850.00
5/10/20/50/100/200/500/1000	100	BAVOMO	874.00

Sensitivity of voltmeters is approximately 1000 Ω/v.

MULTIRANGE MILLIAMMETERS

Range	Scale Div.	Code	Price
*.03/.15/.3/1.5/3/15/30/150/300	150	BAMILXO	$1050.00
.05/.1/.5/1/5/10/50/100	100	BAMILJI	920.00
.1/.5/1/5/10/50/100/500	100	BAMILEK	875.00
.5/1/5/10/50/100/500/1000	100	BAMILUK	775.00
.3/.75/1.5/3/7.5/15/30/75/150	150	BAMILOP	800.00
1/2/5/10/20/50/100/200/500/1000	100	BAMILOO	834.00
1.5/3/7.5/15/30/75/150/300/750/1500	150	BAMILEE	834.00

**Accuracy .15%*

SINGLE RANGE MILLIAMMETERS

Any single range milliammeter from 1 ma full scale, Price **$565.00**

AMMETERS

Range	Scale Div.	Code	Price
.3/1.5/3/15/30	150	BAANKET	$976.00
5/10/20/50	100	BAAMEX	995.00

Supplied with matching external shunt boxes, 12" x 9" x 5" h; approx. max. weight 12 lbs. net; 16 lbs. shipping

MODEL L AC/DC LABORATORY STANDARD VOLTMETERS, MILLIAMMETERS & AMMETERS

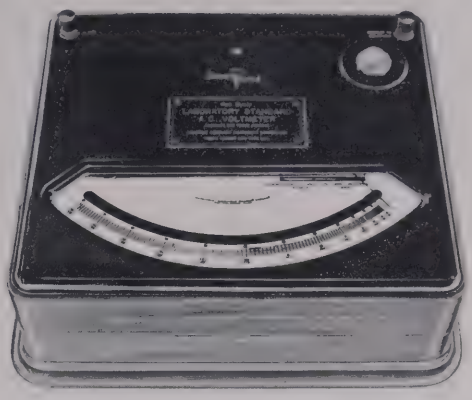
MODEL L

SPECIFICATIONS

AC/DC LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.1% of full scale
FREQUENCY	DC and 25 cps to 125 cps or DC and 50 cps to 400 cps. Instruments can be supplied on special order compensated from 50 cps to 1000 cps or at a particular frequency up to 1000 cps.
TYPE	Electrodynamometer; true rms response
SCALE	Vernier; hand-drawn; 12"; anti-parallax mirror
POINTER	Knife edge
PERIOD	4 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts
MECHANICAL ZERO	External zero shifter
CASE	Walnut; 16½" x 14½" x 5" h; black bakelite panel. (Multipliers or shunt boxes, 12" x 9" x 5" h)
APPROX. WEIGHT	17 lbs. net; 50 lbs. shipping. (Multipliers and shunt boxes when supplied add from 10 lbs. to 25 lbs. to shipping weight.)

All instruments are provided with data listing temperature corrections and maximum overload ratings.

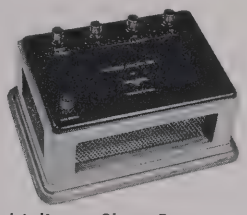


GENERAL DESCRIPTION

The Model L is a .1% accurate AC/DC electrodynamometer type Laboratory Standard. While primarily designed for measurements of AC from 50 cps to 400 cps, it can be conveniently calibrated on reversed DC. It features true rms response regardless of wave form variations. The Model L not only measures accurately in absolute values but also makes an excellent AC/DC transfer standard within its frequency range.

Voltmeters and 25 cps to 125 cps instruments with current ranges above 300 ma are normally furnished with external multipliers or shunt boxes. This is an important feature since dynamometers draw appreciable power and self-heating would otherwise be enough of a problem to necessitate the installation of shunt circuits or open circuit tapping keys, or otherwise limit the duty cycle of the instrument. If a self-contained instrument is required where not normally furnished, in most cases it can be supplied, but with the aforementioned limitations. Voltmeters are furnished with one lead for connection to their multiplier case; milliammeters and ammeters are supplied with three leads for connection to their shunt box.

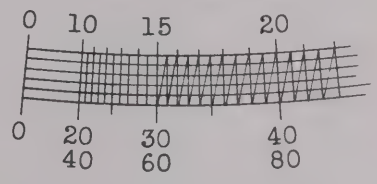
OPTIONAL SPECIFICATIONS



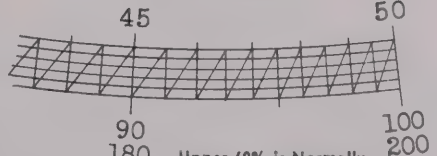
Multiplier or Shunt Box

1. Instruments with special scales and/or ranges available. Multirange instruments can be frequency compensated for use at any single frequency up to 1000 cycles provided they have a ratio of no greater than 2 to 1 from highest to lowest range. Single range instruments can be compensated for use at a particular frequency anywhere from 25 cps to 1000 cps. Instruments compensated for use at a higher frequency have a higher burden than those designed for 25 cps to 125 cps measurements. Correspondence invited.

Model L Facsimile Scale



Scale is Shown in Two Sections



Upper 60% is Normally Expanded as Illustrated

MILLIAMMETERS

	DC and 25 cps to 125 cps				DC and 50 cps to 400 cps		
Range	Approx. Burden in VA at 60 Cycles	Scale Div.	Code	Price	Code	Approx. Burden in VA at 60 Cycles	Price
50/100	2	100	LABMIL	$805.00	LABMIL-X	50	$1005.00
75/150	3	150	LABNOT	805.00	LABNOT-X	50	1005.00
100/200	4	100	LABNAK	805.00	LABNAK-X	40	1005.00
150/300	3	150	LABMOR	805.00	LABMOR-X	40	1005.00
500/1000	3	100	LABMUD	805.00	LABMUD-X	40	1005.00
750/1500	6	150	LABMEX	815.00	LABMEX-X	40	1015.00

AMMETERS

1/2	6	100	LABAST	$822.00	LABAST-X	40	1022.00
1.5/3	9	150	LABAMP	822.00	LABAMP-X	40	1022.00
2.5/5	10	125/100	LABAMK	822.00	LABAMK-X	40	1072.00
5/10	15	100	LABAMI	822.00			
7.5/15	26	150	LABAMU	860.00			
10/20	24	100	LABAMO	872.00			

VOLTMETERS

DC and 25 cps to 125 cps

Range	Approx. Ω/v	Scale Div.	Code	Price
75/150/300	22	150	LABVOI	$850.00
30/75/150/300	20	150	LABVOL	942.00
50/100/200/500	24	100	LABVOM	958.00
75/150/300/750	22	150	LABVOS	984.00
100/200/500/1000	44	100	LABVOX	1002.00

DC and 50 cps to 400 cps

Range	Approx. Ω/v	Scale Div.	Code	Price
30/75/150	6	150	LABVOP-X	$975.00
50/100/200	10	100	LABVOK-X	1050.00
75/150/300	10	150	LABVOI-X	1075.00
100/200/500	18	100	LABVOA-X	1120.00
150/300/750	20	150	LABVOB-X	1160.00
200/500/1000	30	100	LABVOC-X	1200.00

MODEL LW
AC/DC LABORATORY STANDARD WATTMETERS

SPECIFICATIONS

AC/DC LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.1% of full scale
POWER FACTOR	80% to 100%
FREQUENCY	DC and 25 cps to 125 cps
TYPE	Electrodynamometer single phase wattmeter
OVERLOAD RATING	a. Current circuit: 100% of normal current rating b. Potential circuit: 60% of normal voltage rating

All other specifications the same as for the Model L on page 67.

OPTIONAL SPECIFICATIONS

1. Instruments with special ranges and/or scales available. Correspondence required.

GENERAL DESCRIPTION

The Model LW is a self-contained, single phase, .1% accurate, AC/DC Laboratory Standard electrodynamometer wattmeter. It is designed primarily for the calibration of other wattmeters or the measurement of power down to 80% PF, from 25 watts to 6000 watts full scale.

While the Model LW is similar in construction to other laboratory standard electrodynamometer instruments its fundamental application in the measurement of AC power greatly increases the complexity of its design. In a voltmeter and an ammeter a single current flows through both the moving coil and the stationary field coils. The fundamental equation for instrument torque is as follows:

$$\text{Torque} = KNI_{mc} \times NI_{fc} \times \text{Cos}\theta$$

where
- NI_{mc} = Ampere turns in moving coil
- NI_{fc} = Ampere turns in field coil
- θ = Phase angle between two coil currents
- K = Calibration constant

As I_{mc} and I_{fc} are the same current, Cosθ is unity and drops out of the picture. (Cosθ may not be unity in shunted types of ammeters but it is at least constant and appears as part of calibration constant K.) In the wattmeter the potential circuit furnishes NI_{mc}, the current circuit furnishes NI_{fc}, and Cosθ is variable and can be any value within the power factor rating of the instrument. Herein lies one of the basic design problems. The fundamental torque equation given previously is as it is usually stated. Actually, however, it is as follows:

$$\text{Torque} = K \phi mc \times \phi fc \times \text{Cos}\theta$$

ϕ = flux produced by the coils

MODEL LW

In other words the actual torque is proportional not to the ampere turns but to the fluxes produced by those ampere turns. Ordinarily, in air cored coils, the flux is considered to be identical in phase to the current, but actually in any realizable coil there are some eddy current effects which cause the phase of the flux to lag the current producing it by some slight amount. These eddy currents are in the metal supports for the coils, in the shield and even in the coil conductors themselves. These lagging fluxes are not identically delayed in both the fields and the moving coil. The difference in these two delays is effectively added or subtracted from Cosθ as an error effect.

A shield design has been developed especially for the Model LW instrument and uses the best of the new thin gauge crystal aligned silicon steels. Metal supports have been designed using high resistivity alloys. These precautions have been combined to keep the actual phase angle error of the Model LW down to a minimum. The fundamental DC and (100% PF) AC calibration of the Model LW is guaranteed accurate within ±.1%. AC/DC difference tests are made on each instrument. Acceptable instruments show errors equivalent to less than 2 minutes of phase angle.

A further discussion of wattmeters for both single phase and polyphase measurements is given in Section 5. Reference standard and other portable wattmeters are catalogued with accuracies to .25%, frequency compensation to 2500 cycles, and power factor ratings down to 20%.

RANGES

Note: *Watt ranges are obtained by cross multiplying potential ranges and normal current ranges. To assist the reader, the instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGES			CURRENT RANGES							
			Normal		Maximum					
50 Volts (75 Volts Max.)	100 Volts (150 Volts Max.)	200 Volts (300 Volts Max.)	Series	Parallel	Series	Parallel	Scale Div.	Range Printed*	CODE	Price
25/50	50/100	100/200	.33	.66	.66	1.33	100	100	LWATTO	$1205.00
37.5/75	75/150	150/300	.5	1.0	1.0	2.0	150	75	LWATAM	1160.00
75/150	150/300	300/600	1	2	2	4	150	150	LWATER	1160.00
187.5/375	375/750	750/1500	2.5	5	5	10	150	750	LWATHY	1160.00
250/500	500/1000	1000/2000	3.33	6.66	6.66	13.33	100	1000	LWATIS	1160.00
375/750	750/1500	1500/3000	5	10	10	20	150	750	LWATJA	1160.00
500/1000	1000/2000	2000/4000	6.66	13.33	13.33	26.66	100	1000	LWATKO	1205.00
750/1500	1500/3000	3000/6000	10	20	20	40	150	1500	LWATLU	1310.00

*An additional scale can be drawn and printed at a surcharge of $125.00.

MODEL DYL AC LABORATORY STANDARD VOLT-AMP-MILLIAMMETER

MODEL DYL

GENERAL DESCRIPTION

The Model DYL is a transformer-coupled electrodynamometer Laboratory Standard with 15 self contained full scale ranges for measuring AC current and voltage over a frequency span of 50 cps to 70 cps. It measures AC without the necessity of performing AC/DC transfer measurements. When used as a calibration standard, AC indicating instruments can be certified directly on AC, and unless pertinent to their operation, a time consuming reversed DC check does not have to be performed. All ranges are switch controlled enabling quick selection of the correct operating range. Ranges are overlapping, and since the characteristics of the scale are approximately square law, maximum accuracy and resolution is assured by always reading at or near full scale where the scale divisions are greatly expanded. Reading is true rms regardless of wave form.

SPECIFICATIONS

AC LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.1% of full scale
FREQUENCY	50 cps to 70 cps
TYPE	Transformer coupled electrodynamometer; true rms response
SENSITIVITY	Approx. .3 watts all current ranges, 10 watts all voltage ranges
SCALE	Vernier; hand-drawn; 12"; anti-parallax mirror
SCALE DIVISIONS	100 div. printed 0-50/100/200
POINTER	Knife edge
PERIOD	4 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Walnut; 24" x 14" x 8" h; black bakelite panel; walnut dust cover
APPROX. WEIGHT	30 lbs. net; 50 lbs. shipping

All instruments are provided with data listing temperature corrections and maximum overload ratings.

RANGES

AC Voltage: 20/50/100/200/500 volts
AC Current: 10/20/50/100/200/500 ma; 1/2/5/10 amps

Model	Frequency Span	Code	Price
DYL	50 cps to 70 cps	DYNLAB-S	$1780.00

MODEL CHC HEAVY CURRENT DC AMMETER

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.2% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SENSITIVITY	All ranges approx. 50 mv drop
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	a. Code CHARLIE: 100 div. printed 0-10/20/50 amps b. Code CHARITA: 150 div. printed 0-15/30/75 amps
POINTER	Knife edge
PERIOD	2 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	"Plug-in" range selection
MAGNETIC SHUNT	Internal; 3% max. adjustment
TEMPERATURE COEFFICIENT	Compensated from 20°C to 30°C
MECHANICAL ZERO	External zero shifter
CASE	Formica; 15⅞" x 10⅜" x 8" h; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	21 lbs. net; 48 lbs. shipping

Model	Ranges	Code	Price
CHC	0-1/5/10/20/50/100 amps	CHARLIE	$875.00
	0-1.5/3/7.5/15/30/75 amps	CHARITA	875.00

GENERAL DESCRIPTION

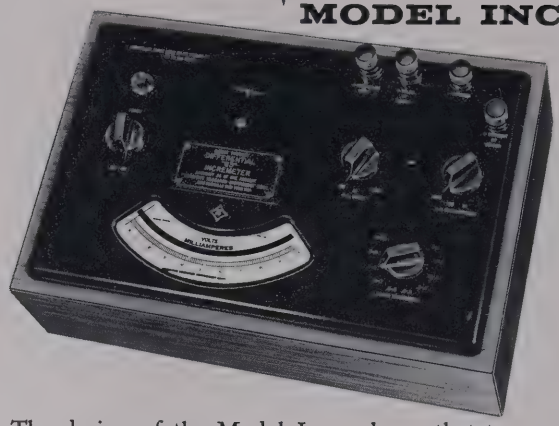
The Model CHC is a self contained DC ammeter designed to simplify and speed up heavy current measurements. It has 6 overlapping ranges and is offered in a choice of two range combinations covering a measuring span of 1 to 100 amps or 1.5 to 75 amps full scale.

Range selection is accomplished by changing only a single "plug-in" connection. The necessity of transporting a series of shunts, leads and a millivoltmeter, and connecting them to each other (and reconnecting for each range change) is entirely eliminated.

A spare range connection plug is placed in a dummy hole on the instrument's front panel for easy accessibility and use if necessary.

MODEL INCRE 'EXPANDED SCALE' DC VOLT-AMP-MILLIAMMETER

MODEL INCRE



SPECIFICATIONS

DC PORTABLE LABORATORY STANDARD—HORIZONTAL USE

ACCURACY	.05% of full scale
TYPE	Permanent magnet, double pivoted moving coil system. Differential circuit standardized by a Zener diode regulated voltage source. Expanded scale in increments of 10% of full scale range.
SCALE	Hand-drawn; actual scale length 6.3"—effective scale length 63"; anti-parallax mirror
SCALE DIVISIONS	Actual number of divisions 100—effective number of divisions 1000
RESOLUTION	.1%/div. (Scale can be read to .01%)
POINTER	Knife edge
PERIOD	5 seconds
RESPONSE TIME	3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
POWER REQUIREMENTS	115 v, 60 cps (25 va). Regulation of Zener source is within .01% for line voltage variations of 90 v to 130 v.
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% maximum adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 15⅞" x 10⅜" x 8" h; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	25 lbs. net; 47 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. Instruments can be supplied with special range combinations and/or special scales. Full scale sensitivities are available from 100 μa to 30 amperes and 100 mv to 1500 v. The main limitation in supplying special ranges is scale readability. Any single range or multirange instrument can be supplied with numerical full scale values of either 1, 1.5, 3 or 5, and/or their multiples of 10 thereafter. The best readability is obtained with values of 1 or 5, and/or their multiples of 10. These ranges can be read directly on the scale and incremental switch of the instrument as a continuous number. Ranges of 1.5 or 3, and/or their multiples of 10 are read as the addition of the scale indication and incremental switch values. Reading is simple in either instance but slightly faster in the former case. For special ranges any single scale, single range instrument can be made in which the beginning of the scale is not more than 14/15 of the full scale value. By drawing separate scales, three such ranges can be combined in one instrument. Reading is a continuous number for each expansion. The maximum sensitivities of 100 μa and 100 mv are not available in the same instrument. Correspondence is invited on special instruments.

2. Specially designed overload protection can be furnished for individual applications. Correspondence invited.

GENERAL DESCRIPTION

The Model Incre is an expanded scale DC Volt-Amp-Milliammeter featuring (1) *an effective scale length of 63",* (2) *an effective resolution of 1000 divisions,* (.1%/division that can be further interpolated to .01%), (3) *precision of better than .01% and,* (4) *accuracy of .05% of full scale.*

The design of the Model Incre shows that two separate coils are wound on the same moving assembly. In operation currents of opposite polarity are applied to the coils. The resulting torque is proportional to the difference between the applied currents. One of the coils carries a reference current stabilized by a Zener diode network and the other is supplied by an unknown current to be measured. Using these techniques improved readability and higher orders of accuracies are obtainable.

The current required to deflect the instrument's pointer to full scale is relatively small compared to the current-carrying capacity of the coil wire. Larger currents can, therefore, be applied without causing overheating or damage to the coil. The net result of using the differential movement in this manner is physically to expand every 10% of each full scale range over the instrument's actual 6.3" scale length. While the accuracy of the basic differential instrument employed is a nominal .5% or better of full scale, because comparisons are made at 10 $\times$ the rating for normal full scale deflection, resolution and accuracy are increased by a factor of 10. An explanation of the basic circuit is given in Fig. 1. (The differential instrument is described in Sec. 9.)

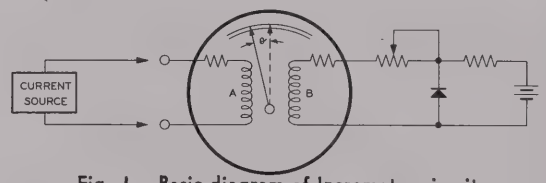


Fig. 1. Basic diagram of Incremeter circuit

Current is supplied to Coil A from an unknown source. A reference current is applied to Coil B through a Zener diode stabilized network. Assuming 49 ma in one coil and 50 ma in the other, the net torque causes a deflection which is marked as one scale division. If the 50 ma is accurately known, the smaller current must be 49 ma (50 minus 1). The comparison sensitivity is then 2% (per division). To take advantage of the inherent overload capabilities of the differential moving coil system, currents of 499 and 500 ma can be used. Again, a one-division deflection is obtained but comparison sensitivity is .2%, instead of 2%, a gain in comparison sensitivity of 10 times. This is so because in actual values accuracy of $\pm$1 ma in 50 ma becomes $\pm$1 ma in 500 ma.

The Zener diode regulated voltage source employed as a continuous reference is similar to the Model STV described on page 60. It has a stability guarantee of $\pm$.01%. Data on this reference indicates stabilities of $\pm$.005% are obtainable for periods of more than a year.

MODEL INCRE 'EXPANDED SCALE' DC VOLT-AMP-MILLIAMMETER

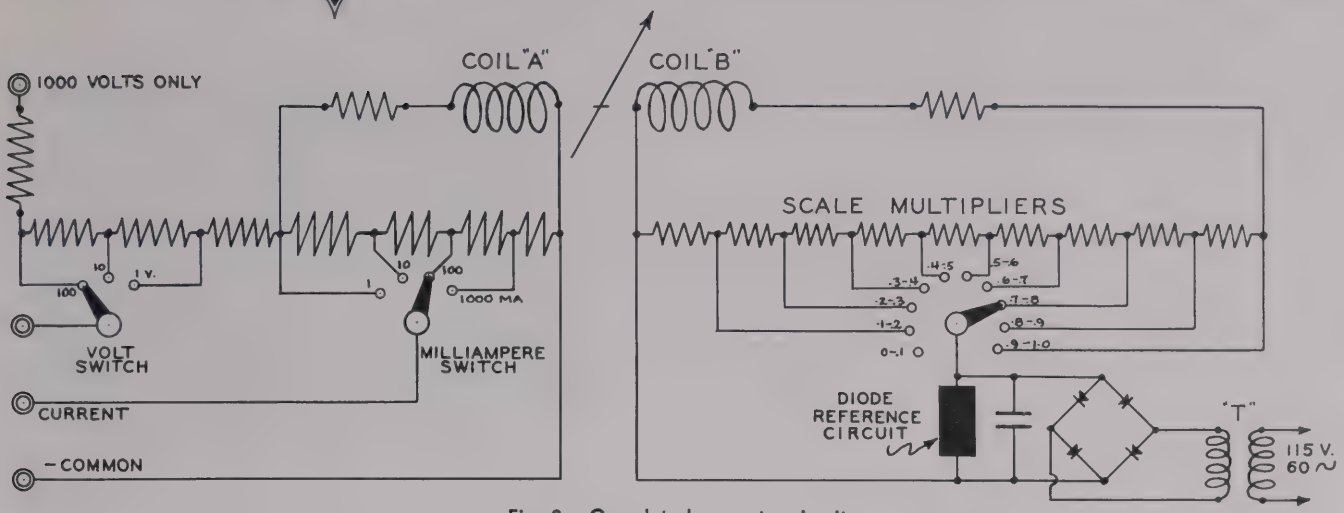


Fig. 2. Complete Incremeter circuit

Fig. 2 shows the complete Incremeter circuit for the Code SUPRES, and a full description of its operation is given below.

The differential movement is combined with a stable Zener diode reference source which supplies a reference 1 ma with a stability of better than .01%. Assuming a basic differential movement of 0 to 100 μa of each coil, if S1 is on the most sensitive current range (0 to 1 ma), and S2 is set at 0 to .1, there is no reference current supplied and the instrument deflects full scale for an input of 100 μa (.1 of 1 ma). If suppression switch S2 is turned from .1 to the .2 position, a portion of the reference current is fed into the other half of the instrument moving coil system. Actually, 100 μa are flowing in the reference half and it takes 100 μa from the external source merely to bring the pointer to zero. Therefore, 200 μa are required from the unknown source for full scale deflection. Thus, the scale now reads not 0 to .1 ma but .1 to .2 ma. As S2 is rotated, greater currents are put through the reference half of the differential moving coil system and the other side reads progressively .2 to .3 ma, .3 to .4 ma and so on until the scale reading is .9 to 1 ma with 900 μa flowing in the reference circuit. In effect, each tenth of the normal 0 to 1 ma scale of 6.3 inches is expanded into full scale deflection. Total effective scale length is then 63 inches.

For any given range of S1, there are 10 different sets of scale readings available from 0 to .1 to .9 to 1 of the particular range involved. Accuracy is stated in terms of the full scale value of the range in use, regardless of what particular small section of that range the scale may be reading at the moment. This means that the 1 v range, spread over 63 inches of total scale length with 1000 scale divisions, has an accuracy of .05% of full scale (.05% of 1 v) which is ±.5 mv.

RANGES

DC Voltage:	1	10	100	1000 v
Approx. Sensitivity:	1000 Ω/v			

DC Current:	1	10	100	1000 ma
Approx. Sensitivity:	850	235	25	2.5 Ω

Model INCRE **Code SUPRES** **Price: $840.00**

Note: Any single range voltmeter with a single incremental expansion (suppressed zero) between 1 v and 500 v, price $464.00; over 500 v to 1000 v, price $479.00. A maximum of 2 ranges can be added at $35.00 each, the base price being determined by the highest volt range.

For single range instruments that are supplied with 10 or 15 incremental expansions, add **$225.00** to the base price.

Panel mounted Incremeters, with a single incremental expansion, can be supplied at an additional cost of $50.00.

Any single range current instrument, with a single incremental range expansion (suppressed zero), between 1 ma and 1 ampere, price $464.00. A maximum of 2 ranges can be added at $35.00 each.

For special ranges any single scale, single range instrument can be made in which the beginning of the scale is not more than 14/15 of the full scale value. By drawing separate scales, three such ranges can be combined in one instrument.

PANEL INSTRUMENTS

MODEL INCRE
FOR RACK MOUNTING

The Model INCRE is also available mounted on a 19" x 8¾" black bakelite panel for rack mounting (see photo). The indicator is housed in a shallow Type EW-7A edgewise panel case with a 7" scale. (The EW-7A case is described in Section 3.) Performance characteristics are the same as for the portable model except effective scale length is 70". **Specify:** Model INCREEW-7A. Code SUPRES. **Price:** $890.00.

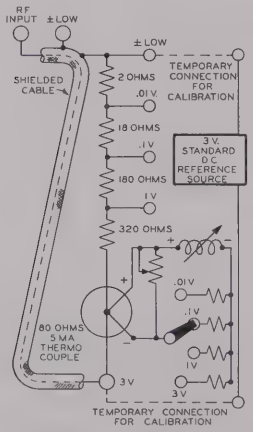
SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale on ranges of .1/1/3 v; 1% on .01 v range
FREQUENCY	DC to 10 mc
TYPE	Thermocouple with permanent magnet, double pivoted moving coil system. Internal Zener diode reference source for autocalibration. True rms response.
SENSITIVITY	200 Ω/v approx.
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	.01/.1/1 v ranges 100 div.; 3 v range 150 div.
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
OVERLOAD RATING	100% of full scale
SHIELDING	Electrostatic
TEMPERATURE COEFFICIENT	"Self Checking" system provides automatic temperature compensation from 20°C to 30°C.
RANGE CHANGING	Input ranges switch controlled; output ranges on separate binding posts. (See Figs. 1 and 2)
SELF CHECKING SYSTEM	.05% accurate internal Zener diode stabilized source
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
POWER REQUIREMENTS	115 v 60 cps to operate the internal reference source (25 watts approx.)
CASE	Formica; 15⅞" x 10⅜" x 8" h; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	25 lbs. net; 47 lbs. shipping

GENERAL DESCRIPTION

The Model RFVC is a thermocouple type voltage calibrator specifically designed for the calibration of vacuum tube voltmeters between DC and 10 mc. It contains an internal Zener diode source that is used to compensate if necessary for changes in the long term stability of the thermoelement. In the event that there are ambient temperature variations or thermocouple aging effects present, a shunt resistance circuit is provided across the junction of the thermocouple and is used to adjust the full scale sensitivity of the instrument while connected to the reference circuit. Accuracies guaranteed for all ranges include the AC/DC differences, or the influence of frequency from DC to 10 mc. Response is true rms regardless of wave form distortion in the signal source used.



INTERNAL CIRCUIT OF R.F. VOLTAGE CALIBRATOR

Fig. 1. Basic Circuit of Model RFVC

Figure 1 shows the high frequency portion of the calibrator. It consists of a high frequency voltage divider with a thermal instrument to monitor the current

MODEL RFVC

flowing in it. Taps are provided for the .01/.1/1 v output ranges and the entire divider chain furnishes the 3 v output range. Variation in the absolute values of the resistor employed in the divider are compensated for by a series of resistances in the junction circuit of the thermocouple. A switch selects the proper corrective resistor for the range in use. Since the thermocouple monitors the current through the divider without significant errors from wave form and frequency, a DC calibration of the divider can be accomplished and be expected to hold true for AC over the entire voltage division and frequency range. The divider is in a single straight line for optimum frequency response.

The 200 Ω/v impedance of the divider is low by comparison to the impedance of all types of VTVM's normally encountered. The Model RFVC is, therefore, designed for the calibration of high impedance instruments only. It cannot be used for the calibration of low impedance instruments because the potential taps below 3 v cannot supply appreciable current and still maintain full accuracy. This does not, however, apply to the 3 v range where loading by an external instrument being calibrated shows up only as an additional burden on the generator and does not affect overall accuracy. On the 3 v range the instrument calibrates any indicating instrument which the generator is capable of powering.

Calibrated replacement thermoelements cannot be supplied for field installation. Uncalibrated thermocouples are available but the user must be in a position to redraw all four scales on the instrument, besides doing installation work and recalibration. Correspondence is suggested before field replacement of thermocouples is attempted.

Operation of the Model RFVC is relatively simple although proper high frequency techniques must be observed. Before using the instrument, temporary connections are made from the upper calibration post to "± low" and from the lower calibration post to the 3 v binding post (as shown in dotted lines in Fig. 2). With the power turned on, the standardization control is turned to adjust the instrument to full scale. After standardization on DC, the connections to the 3 v and "± low" terminals are removed and the signal generator is connected to the RF terminals by means of shielded leads. The vacuum tube voltmeter is connected to "± low" and the appropriate voltage terminal by means of short direct leads. The range is selected by connecting to the proper binding post and adjusting the voltage switch to the corresponding range.

MODEL RFVC
RADIO FREQUENCY VOLTAGE CALIBRATOR

Any signal generator may be used which provides an adjustable voltage from zero to 3 v into an approximate 600 Ω load at the frequencies desired. The output controls of the generator must have resolution sufficient to allow accurate pointer positioning of both the calibrator and the vacuum tube voltmeter under test. In the case of operation with generators which are not truly sinusoidal for all frequencies, a disagreement may be found between the calibrator and the VTVM under test even though both are perfectly correct. The response of many types of VTVM's is in terms of either peak or average values and in some cases is a rather indeterminate combination of the two responses. Such instruments normally are calibrated in terms of rms of a sine wave and this difference introduces an error between the VTVM reading and the calibrator on any non-sinusoidal voltage. This must be considered in the use of the Model RFVC.

Model	Ranges	Code	Price
RFVC	.01/.1/1/3 v AC/DC	RFVCON	$840.00

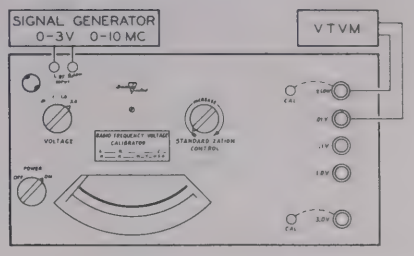


Fig. 2. Using the Model RFVC for Calibrating a VTVM

PANEL MOUNTED INSTRUMENTS

The Model RFVC can be supplied to the same performance specifications on a 19″ x 8¾″ x 5/16″ black bakelite panel for rack mounting. The indicating instrument is housed in a shallow Type EW-7A edgewise panel case with a 7″ scale length. Overall appearance is similar to that pictured for rack mounted Polyrangers as shown in Section 2. The Type EW-7A case is described in Section 7. **Specify:** Model RFVCEW-7A, Code RFVCON. **Price:** $915.00.

MODEL LE LINDECK MICROVOLT SOURCE

SPECIFICATIONS

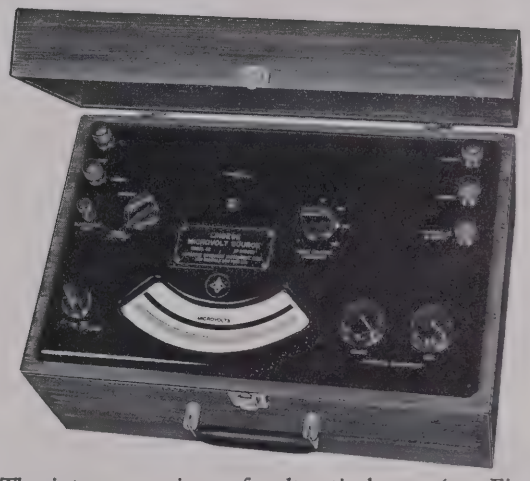
DC PORTABLE—HORIZONTAL USE

*ACCURACY	± (.35% of full scale + .05 μv)
*THERMAL EMFS	Less than .05 μv
OUTPUT RANGES	0-1/2/5/10/20/50/100/200/500 μv; 1/2/5/200 mv; 2 v
TYPE	Lindeck microvolt source
READOUT	Sensitive Research Model C Reference Standard Milliammeter. Accuracy .25% of full scale. Diamond pivoted with spring mounted sapphire jewels. See Section 3 for a complete description of the Model C.
RESOLUTION	.01 μv/div. on 1 μv range
POINTER	Knife edge
PERIOD	1 second
SELF CHECKING	Requires only an external 5 amp source and potentiometer
TEMPERATURE COEFFICIENT	Less than .02%/C°
RANGE CHANGING	Switch controlled excepting .2 and 2 v ranges on binding posts.
CASE	Formica; 15⅞″ x 10⅜″ x 8″ deep; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	21 lbs. net; 43 lbs. shipping

**The accuracy guarantee includes the addition of all possible extraneous signals from operation of the Model LE. In the accuracy statement, "+.05 μv" is the allowance made for the generation of thermals emfs. Such thermals are not always present in the measurement but vary in magnitude depending on operating technique. In-plant tolerances demand that the Model LE have total errors of less than .25% of full scale in final check out. In actual usage thermal emfs seldom exceed .02 μv, and can be reduced by employing recommended operating procedures. Accuracy of the Model C milliammeter as given includes the tolerances of its indicating system, and the adjustment of its shunts.*

GENERAL DESCRIPTION

The Model LE Lindeck element is a precision DC microvolt source with 14 output ranges from 1 μv to 2 v full scale. It is designed primarily for use in such applications as:



- The intercomparison of volt ratio boxes (see Fig. 2), standard cells (see Fig. 3), and decade dividers.
- The detection and measurement of thermal emfs and other DC signals in the microvolt range.

A Lindeck source is the simplest, most economical instrument that can be employed to measure low level voltages. It is often the most accurate. It can be considerably more precise than high range potentiometers which have greater fundamental accuracy but which generate larger thermal emfs since in the measurement of microvoltages the magnitude of such extraneous signals is the significant accuracy factor rather than the basic percentage accuracy. As an example, a potentiometer with an accuracy of ± (.01% of reading + 5 μv) measures 10 μv with a possible error of ± (.001 μv + 5 μv), or ±50%. The Model LE, with a fundamental accuracy of .35% of full scale, measures 10 μv with no greater error than ± (.035 μv + .05 μv) or ±.85%. *In this application, the Lindeck microvolt source is greater than 50 times more accurate than the potentiometer.*

MODEL LE
LINDECK MICROVOLT SOURCE

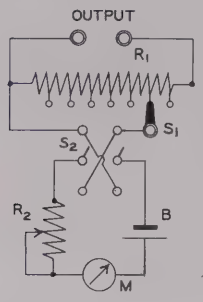


Fig. 1—Basic circuit of the Model LE

The generation of internal thermal emfs by the Model LE is kept to a minimum. The tapped resistor string is designed to handle overloads of 500,000% to preclude self heating. There are no switches, slidewires or other such elements in the potential circuit. All copper terminals and wiring are used throughout.

Resolution is exceptional. Readout is directly in voltage on a 0.25% accurate milliammeter with a 6.3", 100 division scale. (It is possible to interpolate the scale in tenths of a division so that on the 1μv range resolution is $\pm$ .001 μv!)

The basic circuit of the Model LE is shown in Fig. 1. In operation, a current is supplied from an internal battery (B) to create a potential drop across a stable, accurate resistance (R_1) that is tapped and switch controlled to select ranges. The current is adjusted by a variable rheostat (R_2) and measured on a milliammeter (M) to give ranges up to 500 μv FS on the instrument's X1 range. Additional ranges to 5 mv are obtained by switching to a X10 range. All ranges up to 500 μv are multiplied by X10 by decreasing the full scale sensitivity of the milliammeter from 1 ma to 10 ma. A range of .2 v on separate binding posts can also be multiplied by X10 to provide a maximum 2 v output.

Measurements are made by adjusting the output of the LE to null out an unknown emf on a galvanometer. By reading the magnitude of the output, an unknown emf is measured without drawing or supplying a detectable current from either the standard or the instrument under test. The recommended null detector is the COMMANDER Type 5214 Galvanometer Amplifier and SR21 Secondary Galvanometer. (See "Optional Accessories".)

OPTIONAL ACCESSORIES

1. Recommended null detector is the COMMANDER Type 5214 Photocell Amplifier and SR21 Galvanometer. When used with the Model LE they have a combined sensitivity of more than 100 mm div. deflection per μv.

Specify	Price
Type 5214 Photocell Amplifier	$805.00
Type SR21 Galvanometer	283.00

2. The COMMANDER Type 9145 with 4 DPST sections is recommended as a low thermal reversing or circuit selector switch. *Maximum generation of thermal emfs is .01 μv!* It is an essential accessory when stray emfs must be kept to a minimum. The Type 9145 is a design of Dr. T. M. Dauphinee of the Canadian National Research Council. **Specify:** Type 9145, **Price:** $343.00.

COMMANDER Instruments are manufactured in Canada. Duty free prices are available upon request when instrument's usage is for national defense. (See ASPR 6-605.) Prices include duty, brokerage and all handling charges. The F.O.B. point is Rouses Point, N. Y. COMMANDER Instruments are described more completely in Section 11 of this catalog.

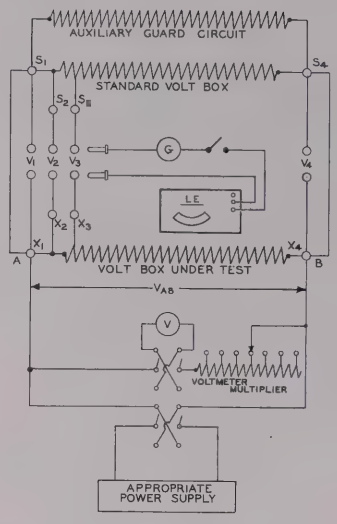


Fig. 2—Volt ratio box comparison circuit

Application of a Lindeck Source

1. Intercomparison of Volt Ratio Boxes. The circuit is as shown in Fig. 2. A standard volt box and the volt box under test are connected in parallel across a power supply. In this case the standard is shown as the COMMANDER Type 9700 or 9700A, volt ratio box constructed to a design described in NBS Research Paper RP1419. The auxiliary guard circuit shown in the diagram is one of the features of its construction. The volt box has an accuracy guarantee of $\pm$10 ppm or better initially and 50 ppm or better for a period of 5 years. The types 9700 and 9700A are described in detail in the COMMANDER Instrument section of the catalog.

In Fig. 2 the voltage (AB) is adjusted to the nominal value at which it is desired to intercompare two volt boxes. (The 2 volt range of the Model LE can be used with the normal output connection of the standard volt box to set the test voltage to an approximate value, eliminating the need for the voltmeter.) The power supply has to be held only to a stable value during the period of test. The voltages V_1, V_2, V_3 and V_4 are measured by the Lindeck microvolt source by adjusting it in each position to indicate zero on the galvanometer (G). This galvanometer must have sufficient sensitivity to detect 1 or 2 microvolts. (See "Optional Accessories.")

The correct ratio of the volt box under test is then
$R = R_S\,(1 + [(V_4 - V_1)/V_{AB}] - R_S\,[(V_3 - V_2)/V_{AB}])$.

The above neglects second order and higher terms in the equation. The readings of the four values V_1, V_2, V_3 and V_4 are taken for all of the volt ratios at which the boxes are to be intercompared and corrections made for any known error with the standard volt box. The voltages V_1, V_2 and V_4 usually are very small values compared to V_3 as they depend only on the resistance of connecting leads. The taking of these lead values can be ignored when measurements of lower accuracy are satisfactory. In this case the formula simplifies $R_X = R_S\,(1 - F_S\,[V_S/V_{AB}])$.

2. Intercomparison of Standard Cells

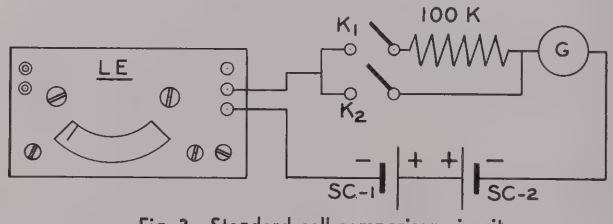
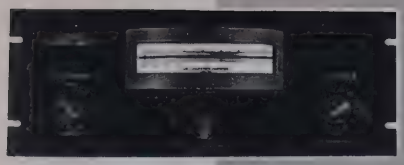


Fig. 3—Standard cell comparison circuit

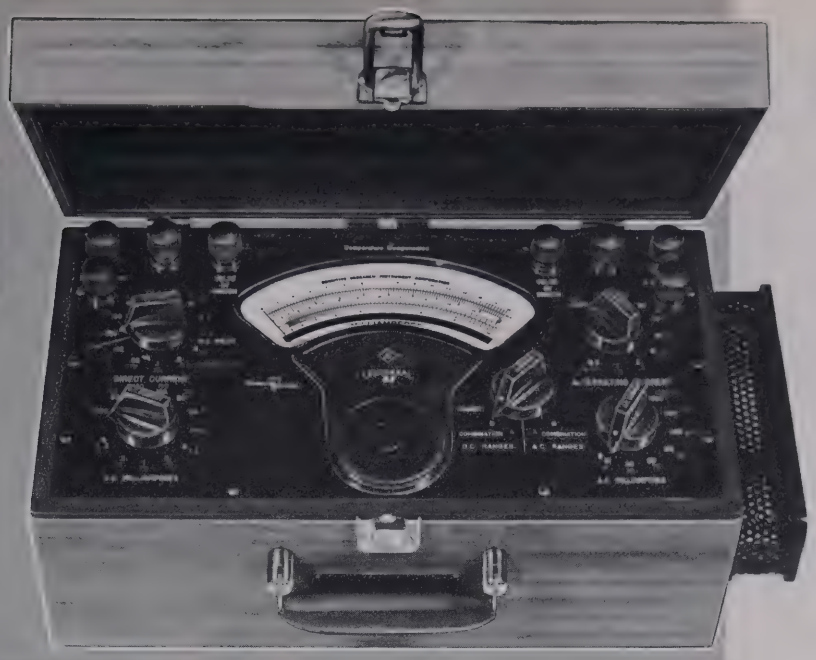
Two standard cells can be compared as shown in Fig. 3. The galvanometer must have sufficient sensitivity to detect a fraction of a microvolt (see "Optional Accessories"). The output of the Lindeck element is adjusted until zero galvanometer deflection is obtained when the keys are depressed. The reading of the Lindeck microvolt source represents the difference between the value of SC 1, the standard, and SC 2, the cell under test.

Model	Ranges	Code	Price
LE	1/2/5/10/20/50/100/200/500 μv; 1/2/5/200 mv; 2v	LINDECK	$565.00

Prices and Specifications Subject to Change Without Notice.
Printed in U.S.A. 75-1



MODEL WVAEW-7A
(RACK MOUNTED MODEL WVA)



MODEL U88

Portable and Rack Panel Mounted AC, DC and AC/DC POLYRANGERS

MULTIRANGE INSTRUMENTS TO MEASURE CURRENT AND VOLTAGE

S. STERLING CO
Manufacturers' Representatives
8300 SOUTH DIXIE DR.
DAYTON 39, OHIO
AX 8-7573

Model	Description	Page
	"About Polyrangers" . . . Thermocouple Replacement . . . Automatic Overload Protection . . . Temperature Compensation	152-153
UX	.5% DC, .5% AC Self Checking Thermocouple Instrument. 51 ranges. 5.2" scale length	154-155
U88	.5% DC, .75% AC Thermocouple Instrument. 88 ranges. 5.2" scale length	156-157
USP	.5% DC, .75% AC Thermocouple Instrument. 28 ranges. 5.2" scale length	158-159
U-SP	.5% DC, .75% AC Thermocouple Instrument. 31 ranges. 5.2" scale length	159
A	.75% AC/DC Thermocouple Instruments. 11 to 14 ranges. 6.3" scale length	160
UVA	.5% DC and .75% AC University Instruments mounted in a single case. 22 ranges. 4" scale lengths	161
WVA	.25% DC Reference Standard. 27 ranges. 6.3" scale length	162
C	.25% DC Reference Standards. 14 ranges. 6.3" scale length	163
S	.5% DC High Sensitivity Reference Standards. 13 ranges. 5.2" scale length	164
NPR	.5% DC General Purpose Instruments. 9 to 11 ranges. 6.1" scale length	165
University	.5% DC Compact General Purpose Instruments. 9 ranges. 4" scale length	165
DYP	.3% AC Transformer Coupled, Dynamometer Instruments. 12 to 20 ranges. 6.3" scale length	166

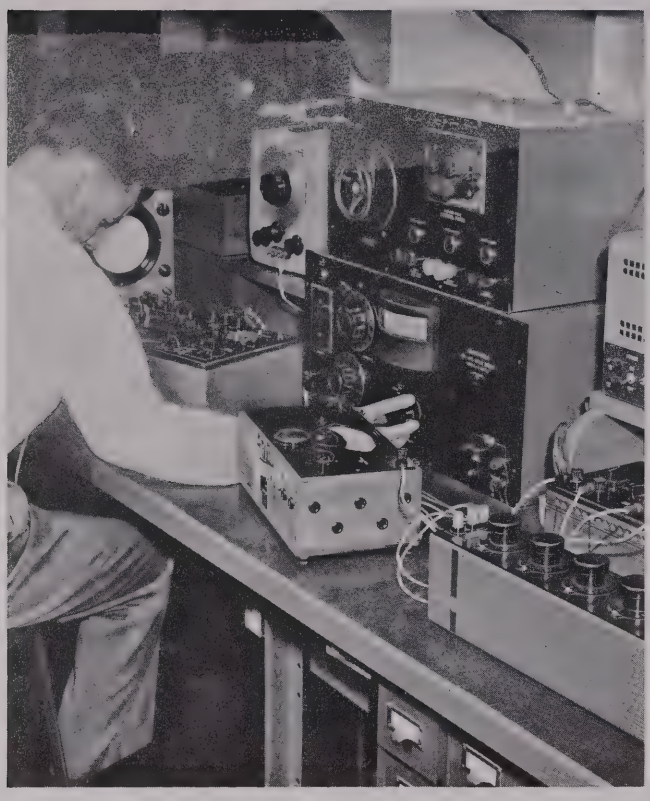
Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N. Y.

Refer to model descriptions for availability of Polyrangers as rack panel mounted instruments.

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *Electrical Measuring Instruments Since 1927*



IN THE LABORATORY

IN PRODUCTION

VERSATILE POLYRANGERS

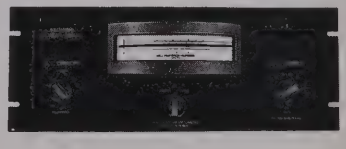
The term "Polyranger" is the copyrighted Sensitive Research trade mark for any AC, DC, or AC/DC multirange electrical indicating instrument for measuring both currents and voltages. The design of a Polyranger offers the user three main advantages (1) versatility (2) a de luxe indicator with a very low cost per full scale range and (3) overlapping ranges which enable most measurements to be made at, or near full scale for maximum accuracy.

Polyrangers are offered as permanent magnet, moving coil instruments for use on DC, transformer-coupled moving irons and electrodynamometers for measuring AC at standard power frequencies, and thermocouple instruments for AC/DC applications necessitating a relatively flat frequency response up to 15 kc. AC and AC/DC types have true rms response. Thermocouple instruments use a permanent magnet, double pivoted moving coil as their basic indicator. In Polyrangers such as the Models UX, U88 and USP there are two measuring circuits; one is for AC/DC use and includes the thermocouple, while the other is for DC use only and bypasses the thermocouple. Because the primary application of a thermocouple is for AC measurements, in the description of these instruments, the AC/DC circuit is simply referred to as the "AC side."

Polyranger designs combine to advantage reliable electromechanical indicators and newer electronic components that enable such features as Self Checking, Automatic Temperature Compensation, Overload Protection and Scale Expansion. Accuracies are as high as .25% of full scale. All Polyrangers have diamond pivots and sapphire spring mounted jewels to give a virtually friction-free moving element that will withstand the severest operating conditions.

Vertically mounted Polyrangers can be supplied in a 19″ x 7″ x 5/16″ black bakelite rack panel to the same performance specifications as portable models. The basic indicator is housed in an edgewise panel case as shown in Section 3, (DC and thermocouple instruments use a shallow case) and Section 4 (Dynamometer instruments use a deep case). Input terminals are furnished on the rear of the panel unless otherwise specified. If a standard grey aluminum panel is desired, a special charge is made for engraving. Rack mounted Polyrangers are furnished with a protective shield.

Rack Mounted Polyranger



THERMOCOUPLE TYPE POLYRANGERS

Sensitive Research thermal elements have excellent AC/DC transfer characteristics. They are selected for their low reversal effect. Consequently the accuracy specification of the thermal side of a Polyranger is the same for both AC and DC. Polyrangers that incorporate thermocouples can, therefore, be calibrated directly on DC and only their AC/DC difference, or frequency influence has to be checked by AC transfer methods.

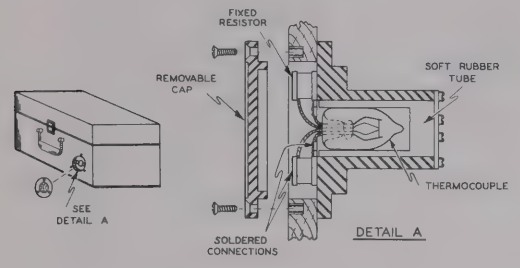


Figure 1. Type 357 TRF

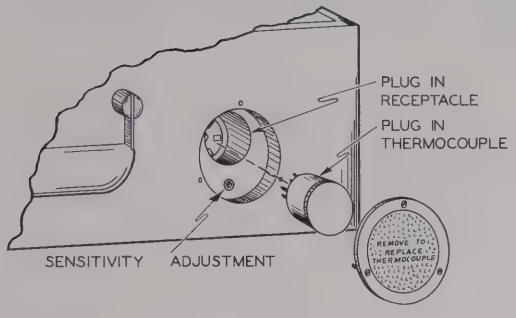
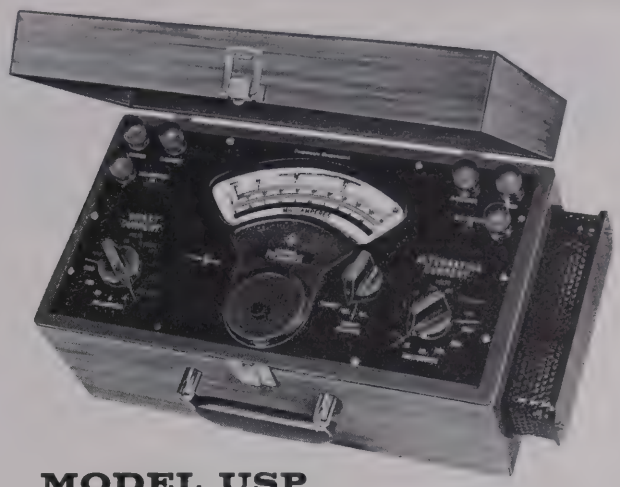


Figure 2. Type 362 TRF

A Thermocouple Replacement Feature (TRF), Type 357, is normally supplied and included in the price of all Polyrangers. Its installation allows for the field replacement of overloaded or burned out thermocouples with the retention of full instrument accuracy. Type 357 replacement thermocouples are furnished with two calibrated fixed resistors which must be soldered into place by the user. (See Figure 1.) The Type 362 is a new optional thermocouple replacement feature that can be substituted for the Type 357. Replacement can be made by "plug-in" instead of soldering. A variable sensitivity resistor is provided to enable the user to adjust full scale deflection of the instrument for maximum scale linearity. (See Figure 2.) The Type 362 is available for all thermocouple Polyrangers excepting the Model A, Comb. 2A.



MODEL USP

AC/DC POLYRANGER . . . a modern laboratory standby

Replacement thermocouples can be ordered by specifying Replacement Thermocouple Type 357 or 362, and when designed for use with existing instruments in the field, the instrument serial number. Instrument thermocouple types are identified for users in the field by a black and silver metallic label mounted adjacent to the thermocouple feature. Delivery of spare thermocouples is from stock.

A correction chart for proper scale linearity is supplied from a calibration record of the millivolt output of the original thermocouple. (See Figure 3.) Most corrections are within the accuracy tolerance of the instrument in which they are to be replaced. If spare thermocouples are ordered at the time of purchasing the instrument, they can be matched for maximum replacement accuracy. Type 362 replacement thermocouples seldom require correction charts.

Automatic overload protection is included for the safeguarding of all thermocouples. Percent of overload protection varies according to the ranges and sensitivities of the individual instruments and is listed in their specifications. This system uses semiconductor techniques to automatically shunt the current around a thermocouple if currents exceed normal full scale values. It preserves the full advantages of thermal type instruments, e.g., true rms response, high frequency operation, and high sensitivity. However, in square loop magnetic material testing or in noise measurements, if sharply peaked waves are imposed, the instrument will begin clipping the top of the spikes at approximately a peak to rms ratio of 4 to 1. Hence waves with greater than this peak to rms ratio will tend to read low. In the event the application makes it desirable, the operator may easily disconnect the protection system from the measuring circuit.

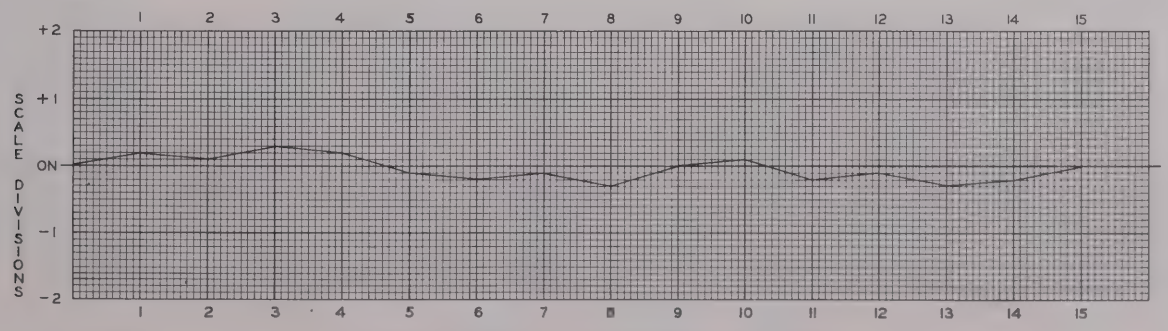
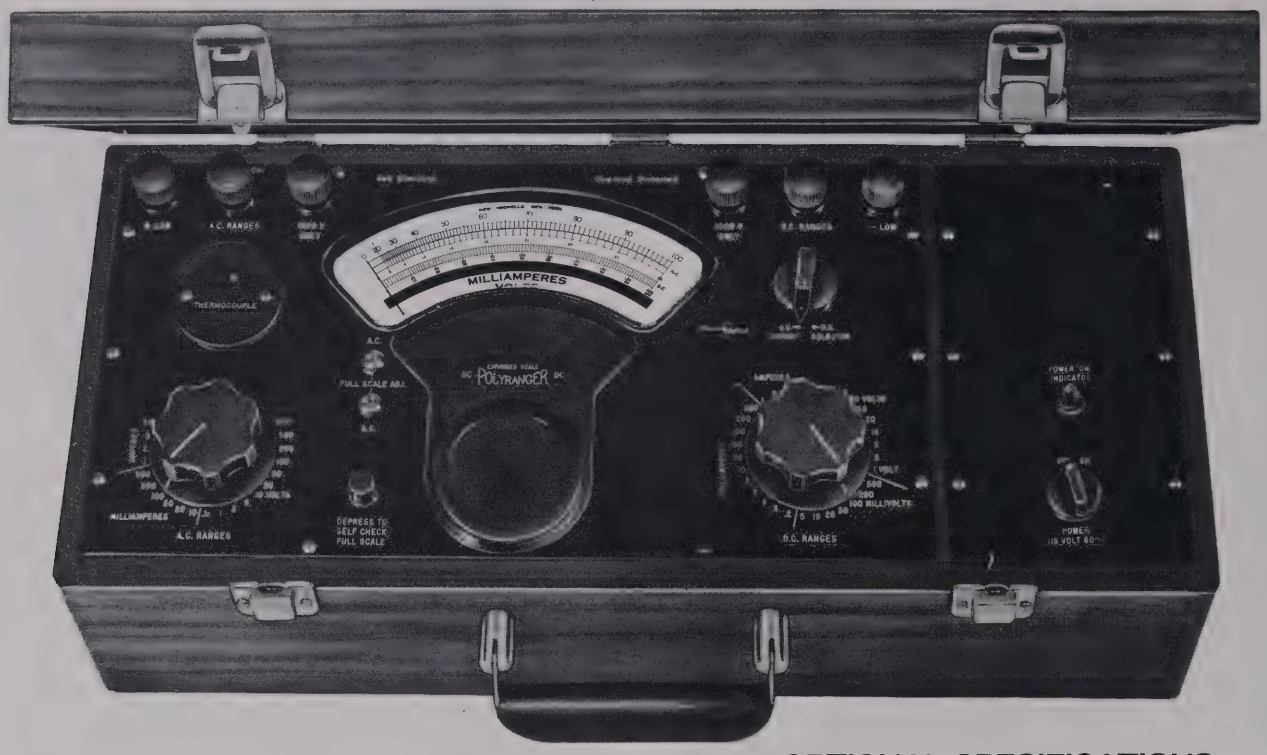


Figure 3. DIVISION ERROR IN INSTRUMENT READING

SELF CHECKING EXPANDED SCALE AC-DC POLYRANGER

MODEL UX



SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
FREQUENCY	DC and 7 cps to 15 kc all ranges excepting ampere ranges to 5 kc. (May be used over a wider frequency span at reduced accuracy.)
TYPE	DC: Permanent magnet, double pivoted moving coil AC: Thermocouple
SENSITIVITY	DC Voltage: 5000 Ω/v AC Voltage: 100 Ω/v All current range resistances, see pg. 155.
SCALE	Hand-drawn; 5.2"; anti-parallax mirror. (AC scale is expanded. Effective scale length is 7.28".)
SCALE DIVISIONS	AC, DC: 100 divisions printed 0-10/20/50
POINTER	Knife edge
PERIOD	DC: 3 seconds; AC: 6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C.
THERMOCOUPLE REPLACEMENT FEATURE	Type 357 (Type 362 optional, see right)
RANGE CHANGING	Switch controlled excepting 1000 v ranges on separate binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 17⅝" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	18 lbs. net; 30 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. A "Plug-in" Thermocouple Replacement Feature (TRF), Type 362, is available. (In the Type 357 normally furnished, replacement thermocouples are soldered into place.) The Type 362 is particularly valuable when installed in the Model UX since its system includes a variable resistance which allows for the adjustment of the sensitivity of the thermocouple. By employing the instrument's Self Checking facility, the output of the thermocouple at full scale deflection can be set for maximum direct reading accuracy without the necessity of using either an external source or standard. Both types of replacement features are described more fully on pages 152 and 153.

If the Type 362 "Plug-in" Thermocouple Replacement Feature is desired, specify and add $25.00 to the price of the Model UX or UXEW-5A.

OPTIONAL ACCESSORIES

1. Spare thermocouples for replacement in the field can be ordered with the Model UX. If ordered after the instrument is in service, the type number of the feature and the serial number of the instrument in which it is to be installed must be specified.

Replacement Thermocouple	Price
TYPE 357	$60.00
TYPE 362	75.00

Reference page 152 and 153 for a complete description of replacement thermocouples.

2. AC and DC voltage ranges and DC current ranges can be extended by the addition of multipliers and shunts. If ordered with the Model UX, they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. If ordered at a future date, overall accuracy is the sum of the accuracies of both units. When ordering multipliers to extend AC voltage ranges, specify frequency at which measurements are to be made.

SELF CHECKING EXPANDED SCALE AC-DC POLYRANGER

Shunts cannot be provided for the extension of AC current ranges since their addition causes variations in scale linearity. Higher AC current ranges can be achieved by employing the Model TR Type 1 Transformer in conjunction with instrument ranges of 2 to 5 amps. **Radio frequency measurements** can be made by taking the output of an external vacuum thermocouple and plotting it on the scale of the 5 or 10 mv DC ranges of the instrument. Vacuum thermocouples with isolated heater junctions can be supplied separately mounted. **Accessory measuring units** such as shunts, multipliers, transformers and thermocouples are described in Section 10.

PANEL MOUNTED INSTRUMENTS

The Model UX is also available for vertical rack panel mounting. The indicator is housed in a Type EW-5A edgewise panel case with a 5" scale length and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model.

Specify: Model UXEW-5A

Price: $970.00

GENERAL DESCRIPTION

The Model UX is a 51 range portable AC/DC electrical indicating instrument featuring increased scale resolution, automatic overload protection and auto-calibration capability. It is designed for those applications demanding a versatile self-contained instrument where good accuracy from DC to 15 kc, operational safeguards and long term reliability are important factors.

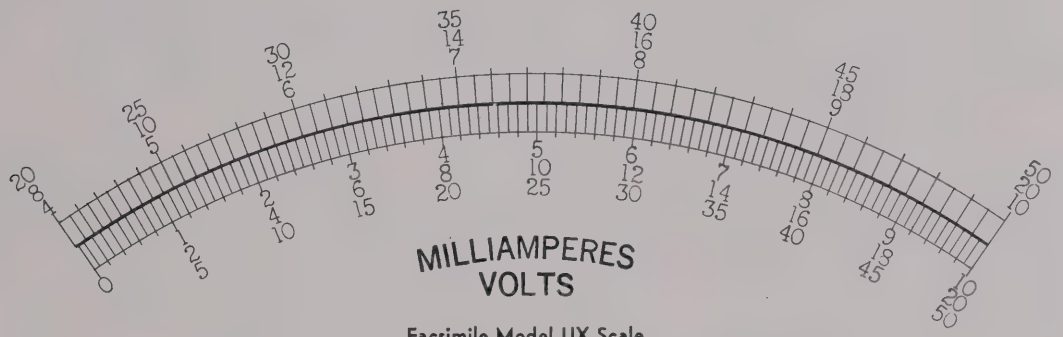
AC resolution is increased by electrically suppressing the first 40% of the full scale range. The ability to make measurements at lower scale values is not affected since all ranges are overlapping and suppression occurs in that area over which accurate readings cannot normally be obtained.

A "Self Checking" system allows for full scale sensitivity calibration (and simple adjustment, if necessary) against a ±.1% accurate, internal Zener diode reference source. The stability of the reference source is guaranteed to ±.05% for a period of one year. Operating power required is 60 cycles, 95 to 135 v. *(50 cps and/or 220 v operation available at an additional charge of $25.00.)*

The automatic overload protection feature enables the thermocouple to withstand overloads of 500% or 10 amps and 500 v above rated voltage, whichever is the lesser figure, without affecting operation or calibration.

The DC and AC circuits of the Model UX are not connected to the moving coil at the same time and, therefore, excessive overloading of the thermocouple circuit does not affect the DC side.

Operation is fast and relatively simple. The instrument is "Self Checked" by depressing a push button on the panel and adjusting for full scale deflection if necessary. Overload protection and temperature compensation are automatic. Ranges are switch controlled (excepting the 1000 v ranges) and all values are clearly engraved. The instrument is direct reading, and because ranges are overlapping, most measurements may be made at, or near, full scale for maximum accuracy.



Facsimile Model UX Scale

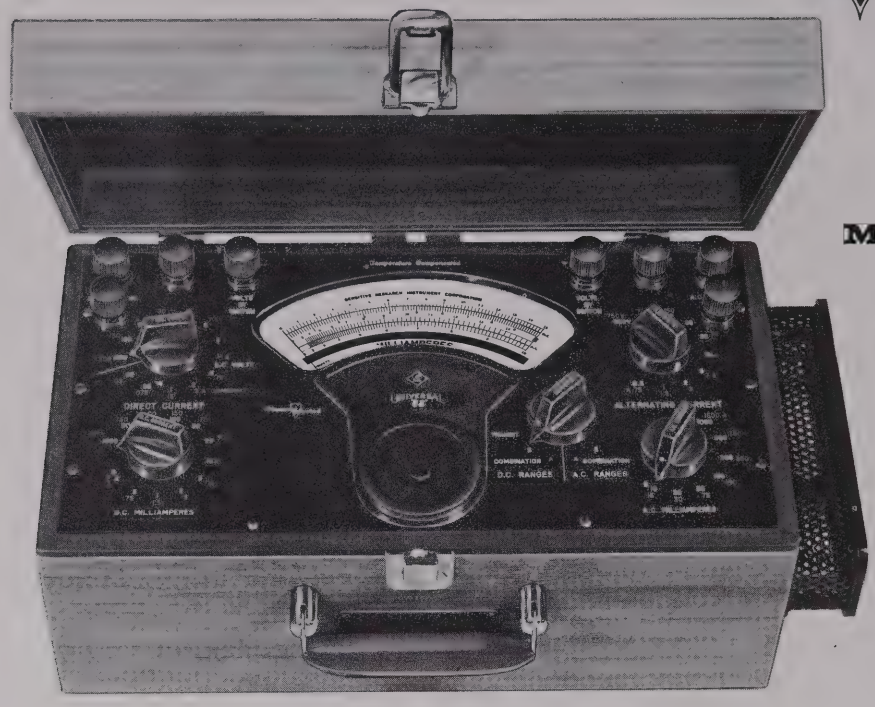
RANGES

DC Voltage:	5	10	20	50	100	200	500 mv	1	2	5	10	20	50	100	200	500	1000 v
Sensitivity:	All ranges 5000 Ω/v																
DC Current:	200	500 μa	1	2	5	10	20	50	100	200	500 ma	1	2	5 amps			
Approx. Resistance:	203	92.5	48	24.6	9.96	5.01	2.53	1.03	.507	.255	.105	.055	.030	.015Ω			

AC Voltage:	.2–.5	1	2	5	10	20	50	100	200	500	1000 v
Sensitivity:	All ranges 100 Ω/v										
AC Current:	4–10	20	50	100	200	500 ma	1	2	5 amps		
Approx. Resistance:	29.84	37.47	20.43	11.13	5.81	2.4	1.22	.601	.244Ω		

Model UX **Code UXSAL** **Price $895.00**

UNIVERSAL 88 POLYRANGER



MODEL U88

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	DC: .5% of full scale AC: .75% of full scale
FREQUENCY	DC and 7 cps to 15 kc for current ranges up to 1 amp; to 5 kc for current ranges above 1 amp and all voltage ranges. (May be used over a wider frequency span at reduced accuracy.)
TYPE	DC: Permanent magnet, double pivoted moving coil AC: Thermocouple
SENSITIVITY	DC voltage: 3333 Ω/v or 5000 Ω/v according to range. AC voltage: 66.6 Ω/v or 100 Ω/v according to range. All current range resistances, see pg. 157.
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
SCALE DIVISIONS	AC, DC: 75/100 divisions printed 0-15/10
POINTER	Knife edge
PERIOD	DC: 3 seconds; AC: 6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
THERMOCOUPLE REPLACEMENT FEATURE	Type 357 (Type 362 optional)
RANGE CHANGING	Switch controlled, excepting 500 and 750 v ranges DC, and 2 and 3 amp ranges AC, on separate binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	10 lbs. net; 19 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. A "Plug-in" Thermocouple Replacement Feature (TRF), Type 362 is available. (In the Type 357 normally furnished, replacement thermocouples are soldered into place.) The Type 362 system includes a variable resistance and, therefore, the output of the thermocouple can be adjusted for optimum full scale deflection and maximum scale linearity when it is checked against an external reference standard. Both types of replacement features are described more fully on pages 152 and 153. If the Type 362 "Plug-in" Thermocouple Replacement Feature is desired, specify and add $25.00 to the price of the Model U88 or U88EW-5A.

OPTIONAL ACCESSORIES

1. Spare thermocouples for replacement in the field can be ordered with the Models U88 and U88EW-5A. If ordered after the instrument is in service, the type number of the feature and the serial number of the instrument in which it is to be installed must be specified.

Replacement Thermocouple	Price
TYPE 357	$60.00
TYPE 362	75.00

Reference pages 152 and 153 for a complete description of replacement thermocouples.

2. AC and DC voltage ranges and DC current ranges can be extended by the addition of multipliers and shunts. If ordered with the Model U88, they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. If ordered at a future date, overall accuracy is the sum of the accuracies of both units. When ordering multipliers to extend AC voltage ranges, specify frequency at which measurements are to be made.

Shunts cannot be provided for the extension of AC current ranges since their addition causes variations in scale linearity. Higher AC current ranges with maximum accuracy can be achieved by employing the Model TR Type 1 Transformer in conjunction with instrument ranges of 2 to 5 amps.

Accessory units such as shunts, multipliers and transformers are described in Section 10.

PANEL MOUNTED INSTRUMENTS

The Model U88 is also available for vertical rack panel mounting. The indicator is housed in a Type EW-5A edgewise panel case with a 5″ scale length and installed in a 19″ x 7″ x 5/16″ black bakelite panel. Performance characteristics are the same as listed for the portable model.

Specify: Model U88EW-5A **Price:** $670.00

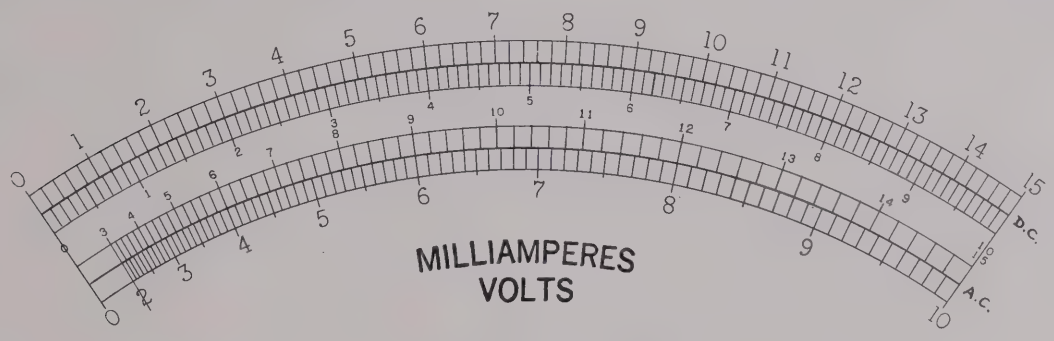
GENERAL DESCRIPTION

The Model U88 is a portable AC/DC electrical indicating instrument with 88 ranges, each overlapping so that all readings can be taken on the upper third of the scale. Since accuracy is in terms of full scale, and the AC scale divisions are greatly expanded in this area, the Model U88 can be employed more advantageously than most instruments for maximum accuracy and resolution.

An automatic overload protection system permits the thermocouple to withstand overloads of 500% or 6 amps and 500 v above rated voltage, whichever is the lesser figure, without affecting operation or calibration. Since the DC and AC circuits of the instrument are not connected to the moving coil at the same time, excessive overloading of the thermocouple circuit does not affect the DC side.

Operation of the Model U88 is facilitated by a simplified method of switching. All ranges are switch controlled (except as noted) and each position designates 2 full scale ranges, one from Combination A, engraved in red, and the other from Combination B, engraved in white. A separate switch is used to select the combination desired. The function of each range switch is specific; i.e., DC volts, DC current, AC volts, AC current, and is engraved on the switch knobs. Separate input terminals are provided for use with each function switch.

The Model U88 is diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Its portable case made of tough, durable formica is gasketed to provide an effective dust and humidity barrier.



Facsimile Model U 88 Scale

RANGES

DC Current:	.2	.3	.5	.75	1	1.5	2	3	5	7.5	10	15	20	30	50	75	100	150	200	300	500	750	1000	1500 ma
Approx. Resistance:	10	60	61.5	70	40	42.3	23.6	23.1	9.6	9.7	4.9	4.9	2.5	2.5	1.0	1.0	0.5	0.5	0.25	0.25	0.1	0.1	.05	.05 Ω

DC Voltage:	.02	.03	.05	.075	.1	.15	.2	.3	.5	.75	1	1.5	2	3	5	7.5 v
Sensitivity:	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333 Ω/v

DC Voltage:	10	15	20	30	50	75	100	150	200	300	500	750 v
Sensitivity:	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333	5000	3333 Ω/v

AC Current:	10	15	20	30	50	75	100	150	200	300	500	750	1000	1500 ma	2	3 amps
Approx. Resistance:	30	20	37.4	34.9	20.1	19.7	10.8	10.6	5.5	5.4	2.4	2.3	1.2	1.1	.6	.6 Ω

AC Voltage:	.5	.75	1	1.5	2	3	5	7.5	10	15	20	30	50	75	100	150	200	300	500	750 v
Sensitivity:	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6	100	66.6 Ω/v

Model U88 **Code EXCEL** **Price $595.00**

UNIVERSAL POLYRANGER

MODEL USP

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	DC: .5% of full scale AC: .75% of full scale
FREQUENCY	DC and 7 cps to 15 kc for current ranges up to 1 amp; to 5 kc for current ranges above 1 amp and all voltage ranges. (May be used over a wider frequency span at reduced accuracy.)
TYPE	DC: Permanent magnet, double pivoted moving coil AC: Thermocouple
SENSITIVITY	DC voltage: 5000 Ω/v on 5 and 50 mv ranges; 1000 Ω/v all other ranges AC voltage: 100 Ω/v All current range resistances, see pg. 159.
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
SCALE DIVISIONS	DC: 100 divisions printed 0-5/200 AC: 75 divisions printed 0-15/30/750
POINTER	Knife edge
PERIOD	DC: 3 seconds; AC: 6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
THERMOCOUPLE REPLACEMENT FEATURE	Type 357 (Type 362 optional)
RANGE CHANGING	Switch controlled, excepting 2 amp DC and 3 amp AC ranges on separate binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	10 lbs. net; 19 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. A "Plug-in" Thermocouple Replacement Feature (TRF), Type 362 is available. (In the Type 357 normally furnished, replacement thermocouples are soldered into place). The Type 362 system includes a variable resistance and, therefore, the output of the thermocouple can be adjusted for optimum full scale deflection and maximum scale linearity when it is checked against an external reference standard. Both types of replacement features are described more fully on pages 152 and 153.

If the Type 362 "Plug-in" Thermocouple Replacement Feature is desired, specify and add $25.00 to the price of the Model USP or USPEW-5A.

OPTIONAL ACCESSORIES

1. Spare thermocouples for replacement in the field can be ordered with the Models USP and USPEW-5A. If ordered after the instrument is in service, the type number of the feature and the serial number of the instrument in which it is to be installed must be specified.

Replacement Thermocouple	Price
TYPE 357	$60.00
TYPE 362	75.00

Reference pages 152 and 153 for a complete description of replacement thermocouples.

2. AC and DC voltage ranges and DC current ranges can be extended by the addition of multipliers and shunts. If ordered with the Model USP, they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. If ordered at a future date, overall accuracy is the sum of the accuracies of both units. When ordering multipliers to extend AC voltage ranges, specify frequency at which measurements are to be made.

Shunts cannot be provided for the extension of AC current ranges since their addition causes variations in scale linearity. Higher AC current ranges with maximum accuracy can be achieved by employing the Model TR Type 1 Transformer in conjunction with instrument ranges of 2 to 5 amps. **Radio frequency measurements** can be made by taking the output of an external vacuum thermocouple and plotting it on the scale of the 5 mv DC range of the instrument. Vacuum thermocouples with isolated heater junctions can be supplied separately mounted. **Accessory measuring units** such as shunts, multipliers, transformers and thermocouples are described in Section 10.

PANEL MOUNTED INSTRUMENTS

The Model USP is also available for vertical rack panel mounting. The indicator is housed in a Type EW-5A edgewise panel case with a 5" scale length and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model.

Specify: Model USPEW-5A

Price: $569.00

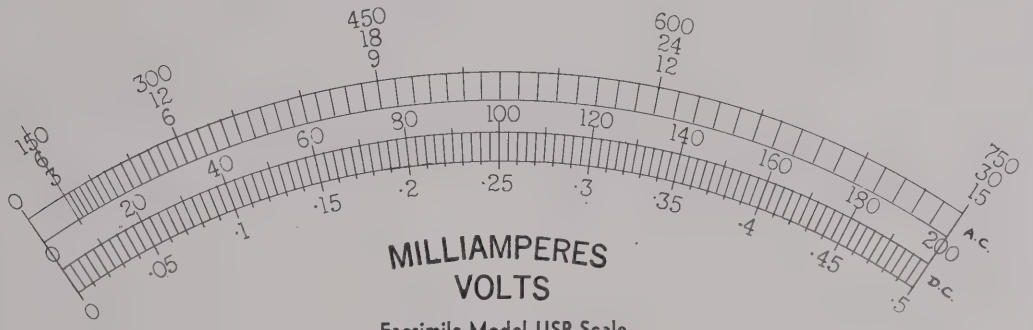
GENERAL DESCRIPTION

The Model USP is a portable AC/DC electrical indicating instrument with 28 overlapping ranges. It has the advantage of being more economically priced than the models UX and U88 (see pages 154 to 157) while still maintaining the versatility of these Polyrangers by covering the same broad measuring range and incorporating some of their most desirable features. The full scale ranges available make it possible to take readings on the upper two thirds of the scale the great majority of the time.

An automatic overload protection system permits the thermocouple to withstand overloads of 500%, or 6 amps and 500 v above rated voltage, whichever is the lesser figure, without affecting operation or calibration. Since the DC and AC circuits of the instrument are not connected to the moving coil at the same time, excessive overloading of the thermocouple circuit does not affect the DC side.

Operation of the Model USP is relatively simple for an instrument with so many ranges. All ranges are switch controlled (except as noted) and separate input terminals for current and voltage are provided for measuring AC or DC. A function switch connects either the AC or DC side to the indicator. The instrument is read directly on an easily interpolated double scale. The AC and DC range combinations, scale markings and scale divisions are different, making it impossible for the user to read the wrong scale.

The Model USP is diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Its portable case made of tough, durable formica is gasketed to provide an effective dust and humidity barrier.



Facsimile Model USP Scale

RANGES

DC Current:	.2	2	20	200	1000 ma	2 amps
Approx. Resist:	10	22.7	2.53	.275	.077	.026Ω
DC Voltage:	5	50	100	500 mv	2	20	200	1000 v
Sensitivity:	5000 Ω/v on 5 and 50 mv ranges; all other ranges 1000 Ω/v					

AC Current:	15	30	150	300	1500 ma	3 amps
Approx. Resist:	40	30	7.65	3.95	.813	.398Ω
AC Voltage:	.3	1.5	3	15	30	150	300	750 v
Sensitivity:	All ranges 100 Ω/v					

Model USP **Code VERSALY** **Price $494.00**

MODEL U-SP

The Model U-SP having similar specifications to the Model USP described above, except as indicated below, was originally developed for use by the United States Air Force. Switch controlled, excepting 2/20 amps and 40/400 v DC, and 3 amps AC, on binding posts. DC voltage sensitivity 5000 Ω/v on 2 and 20 mv ranges; 1000 Ω/v on all others.

RANGES

DC current: .2 / 2 / 20 / 200 / 1000 ma/2 / 20 amps
DC voltage: .002/.02/.1/.2/2/20/40/200/400/1000 volts
AC current: 10 / 30 / 100 / 300 / 1000 / 3000 ma
AC voltage: .3 / 1 / 3 / 10 / 30 / 100 / 300 / 1000 volts

Model U-SP **Code USAFUSP** **Price $590.00**

MODEL A POLYRANGERS

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.75% of full scale
FREQUENCY	DC and 7 cps to 15 kc for current ranges up to 1 amp; to 5 kc for current ranges above 1 amp and all voltage ranges, except 500 v range of Comb. 2A to 3kc. (May be used over a wider frequency span at reduced accuracy.)
TYPE	Thermocouple
SENSITIVITY	All Combs. 100 Ω/v excepting Comb. 2A, 500 Ω/v. All current range resistances listed below
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	Combs. 1-AA, 1-AB, 1-AC, 1-AD: 100 divisions printed 0-10/50 Comb. 2-A: 100/100 divisions printed 0-10/50/200 and 0-2 Comb. 3-A: 100/150 divisions printed 0-50/15
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
THERMOCOUPLE REPLACEMENT	Type 357 (Type 362 optional on all but Comb. 2-A)
RANGE CHANGING	Switch controlled excepting as noted in descriptions of individual range combinations below
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 6⅛" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. A "Plug-in" Thermocouple Replacement Feature (TRF), Type 362, is available for all Model A Polyrangers (excepting the Comb. 2-A). (In the Type 357 normally furnished, replacement thermocouples are soldered into place.) The Type 362 system includes a variable resistor to adjust the full scale output of the thermocouple for optimum scale linearity. (Reference pages 152 and 153.) If the Type 362 "Plug-in" Thermocouple Replacement Feature is desired, specify and add $25.00 to the price of the portable or rack panel mounted range combination ordered.

OPTIONAL ACCESSORIES

1. Spare thermocouples for replacement in the field can be ordered with the Model A portable or panel Polyrangers. If ordered after the instrument is in service, the type number of the feature and the serial number of the instrument in which it is to be installed must be specified. Type 357 thermocouples, $60.00; Type 362, $75.00.

2. Voltage ranges can be extended by the addition of external multipliers. If ordered with the Model A, they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. When ordering multipliers to extend voltage ranges, specify frequency at which measurements are to be made. Higher AC current ranges can be achieved by employing the Model TR Type 1 Transformer in conjunction with instrument ranges of 2 to 5 amps. Accessory measuring units are described in Section 10.

MODEL A

GENERAL DESCRIPTION

The Model A Polyrangers are portable AC/DC electrical indicating instruments whose basic application is the measurement of AC over a wide area of audio frequencies. They differ from the AC/DC Polyrangers previously described in that they are smaller in size, and have one set of input terminals with a single circuit for both AC and DC measurements. The Model A Polyrangers have the advantage of being economically priced while still covering the same broad measuring ranges as other models. The effectiveness of their overlapping ranges is increased because of the exceptional resolution provided by their 6.3" scale length. Operation is simplified by having ranges selected by a single switch.

An Automatic Overload Protection system is provided that enables 100 Ω/v thermocouples to withstand overloads of 500%, or twice the highest current range and 500 v above rated voltage, whichever is the lesser figure, without affecting operation or calibration. The Comb. 2-A utilizing a 500 Ω/v thermocouple can withstand overloads of 5000%, or 1500 v and 2 amps, whichever is the lesser.

PANEL MOUNTED INSTRUMENTS

The Model A Polyrangers are also available for vertical rack panel mounting. The indicator is housed in a Type EW-7A edgewise panel case with a 7" scale length, and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable models. Specify by listing the instrument range combination desired, plus the suffix "EW-7A," i.e. portable combination 1-AA becomes 1-AAEW-7A. Add $75.00 to portable.

COMBINATION 1-AA — **Code AMULTI** — **Price: $385.00**

Current Ranges:	10	50	100	500 ma	1 amp	
Approx. Resist:	30	20	11	2.4	1.2Ω	
Voltage Ranges:	.5	1	5	10	50	100	500 v
Sensitivity:	All ranges 100 Ω/v						

Variations of Code AMULTI have the same ranges plus the following:

COMBINATION:	**1-AB**	**1-AC**	**1-AD**
Additional Ranges:	5 amps*	1000 v	5 amps* & 1000 v
Price:	$405.00	$405.00	$425.00

COMBINATION 2-A — **Code AMULTA** — **Price: $445.00**

Current Ranges:	2	10	50	200	500 ma	1 amp
Approx. Resist:	640	538	124	32	12.8	6.4Ω
Voltage Ranges:	2	10	50	200	500 v	
Sensitivity:	All ranges 500 Ω/v					

COMBINATION 3-A — **Code AMULTO** — **Price: $445.00**

Current Ranges:	15	50	150 ma	.5	1.5	5 amps*	
Approx. Resist:	40	20.4	7.6	2.4	.8	.24Ω	
Voltage Ranges:	.5	1.5	5	15	50	150	500	1500 v*
Sensitivity:	All ranges 100 Ω/v						

* Range on separate binding posts

UNIVERSITY VOLT-AMMETER

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	DC: .5% of full scale AC: .75% of full scale
FREQUENCY	60 cps only (50 cps can be substituted. See "Optional Specifications" below.)
TYPE	DC: Permanent magnet, double pivoted moving coil AC: Transformer-coupled moving iron
SENSITIVITY	See listings below.
SCALES	Hand-drawn; 4"; anti-parallax mirror
SCALE DIVISIONS	DC: 75/100 divisions printed 0-150 and 0-50/100 AC: 75/100 divisions printed 0-150 and 0-50/100
POINTER	Knife edge
PERIOD	DC: 2 seconds AC: 3-4 seconds
DAMPING	DC: Induced emf AC: Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts
MAGNETIC SHUNT	DC only; internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle.
APPROX. WEIGHT	10 lbs. net; 19 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. The Model UVA can be supplied for use on 50 cps only. Specify at time of ordering and add $25.00 to price. Correspondence is invited regarding usage at other single frequencies in the low audio range.

OPTIONAL ACCESSORIES

1. AC and DC voltage and DC current ranges can be extended by the addition of multipliers and shunts. If ordered with the Model UVA they can be supplied so that the direct reading accuracies of the ranges they create are within the accuracy of the instrument. If ordered at a future date, overall accuracy is the sum of the accuracies of both units.

It is impractical to provide shunts for the extension of AC current ranges because of problems involving excessive heat dissipation and temperature coefficient. Higher AC current ranges can be effectively added by employing the Model TR Type 1 Transformer in conjunction with the 5 ampere range of the instrument. Accessory measuring units such as shunts, multipliers and transformers are described in Section 10.

PANEL MOUNTED INSTRUMENTS

The Model UVA is also available for vertical rack panel mounting. The indicators are housed in Model JW-4A cases with 4" scale lengths (see Section 3) and installed in a 19" x 7" x 5/16" black bakelite panel. Specifications and performance characteristics are the same as listed for portables except the scales are drawn with 0-75/50 divisions.

Specify: Model UVAJW-4A **Price:** $395.00

MODEL UVA

GENERAL DESCRIPTION

The Model UVA is a 22 range AC/DC Polyranger consisting of two separate University Model (see Section 3) electrical indicating instruments mounted in a single case. It is offered as a versatile, low cost, rugged indicator that will find wide application in educational institutions and industrial field testing. The instrument is designed for use by relatively inexperienced personnel. All ranges are plainly engraved on separate binding posts, minimizing the danger of connecting incorrectly into a circuit, or of inadvertently selecting the wrong range such as might occur with a switch controlled instrument. Both indicators will easily withstand overloads of 500% without additional protection (100% on 1000 v range). The design of the AC moving iron indicator makes it virtually impossible to mechanically distort the pointer from an electrical overload.

The Model UVA is diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Its portable case made of tough, durable formica is gasketed to provide an effective dust and humidity barrier.

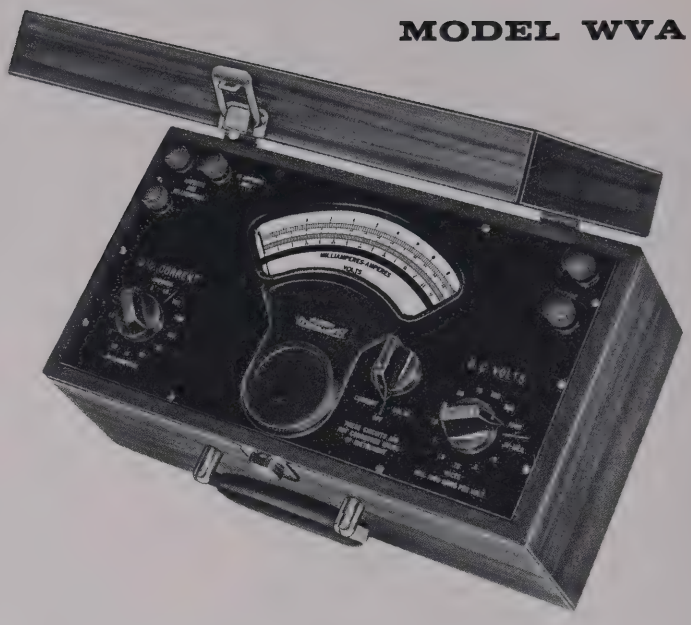
RANGES

DC Current:	1	10	100 ma	1	10 amps		
Approx. Resist:	100	45	5	.5	.05 Ω		
DC Voltage:	50	100 mv	1	10	150	1000 v	
Sensitivity:	All ranges 1000 Ω/v						
AC Current:	10	50	100	500 ma	1	5	10 amps
Approx. Burden:	.52	.68	.73	.75	.93	1.1	1.4 va
AC Voltage:	10	50	150	500 v			
Approx. Burden:	1	2.5	1.5	5 va			

Model UVA **Code UNIVGAMP** **Price $295.00**

WILLIAMSON VOLT AMMETER

MODEL WVA



SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SENSITIVITY	1000 Ω/v; all current range resistances listed below
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	100/150 divisions printed 0-1 and 0-1.5/3/7.5
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled excepting 15 amp range on separate binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	10 lbs. net; 19 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

GENERAL DESCRIPTION

The Model WVA offers the widest measuring capability available in a self-contained DC reference standard indicating instrument. Its 27 overlapping ranges enable readings to be taken at, or near full scale for maximum accuracy. The voltage and current circuits are independent of each other. They are "dummy loaded" so that when current and voltage are supplied at the same time, by reversing the circuit selector switch, almost simultaneous readings can be taken without unbalancing either input. Via this method, values of DC resistance and power can be calculated. The instrument also contains a 0-1 scale which gives a direct reading indication of the current being drawn when making voltage measurements. (0-1 ma full scale = 1000 Ω/v)

The Model WVA is diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Its portable case made of tough, durable formica is gasketed to provide an effective dust and humidity barrier.

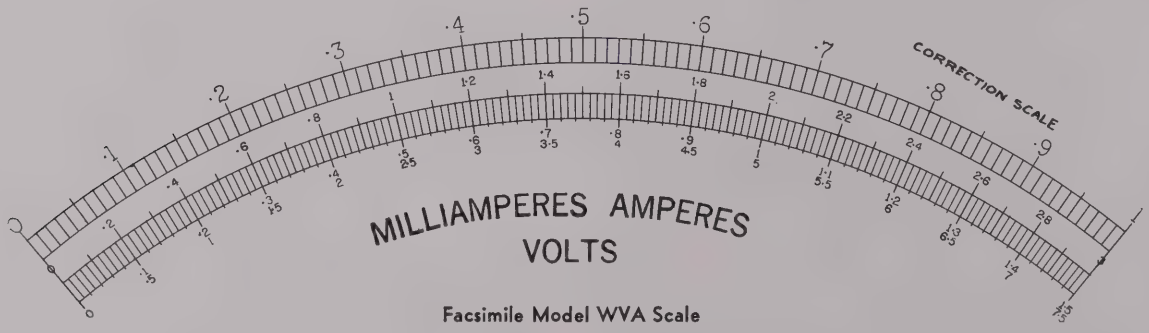
OPTIONAL ACCESSORIES

1. Ranges can be extended by the addition of shunts and multipliers (see Section 10). If ordered with the Model WVA, they can be supplied so that the accuracies of the ranges they create are within the accuracy of the instrument.

PANEL MOUNTED INSTRUMENTS

The Model WVA is also available for vertical rack panel mounting. The indicator is housed in a Type EW-7A edgewise panel case with a 7" scale length, and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model.

Specify: Model WVAEW-7A
Price: $500.00



Facsimile Model WVA Scale

RANGES

Current:	1	1.5	3	7.5	15	30	75	150	300	750 ma	1.5	3	7.5	15 amps
Approx. Resist:	100	66.5	66.5	34.5	18.6	9.62	3.95	1.98	.97	.36	.18	.08	.03	.02 Ω
Voltage:	100	150	300	750 mv	1.5	3	7.5	15	30	75	150	300	1000 v	

Sensitivity: All ranges 1000 Ω/v **Model WVA** **Code WILAM** **Price $425.00**

REFERENCE STANDARD DC POLYRANGERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SENSITIVITY	1000 Ω/v; all current range resistances listed below.
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	Comb. 1-C: 150/100 divisions printed 0-30/100 Comb. 3-C: 150 divisions printed 0-15/30/75 Comb. 4-C: 100 divisions printed 0-50/100
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled excepting ranges of 3 amps or higher and 1000 v on separate binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL ACCESSORIES

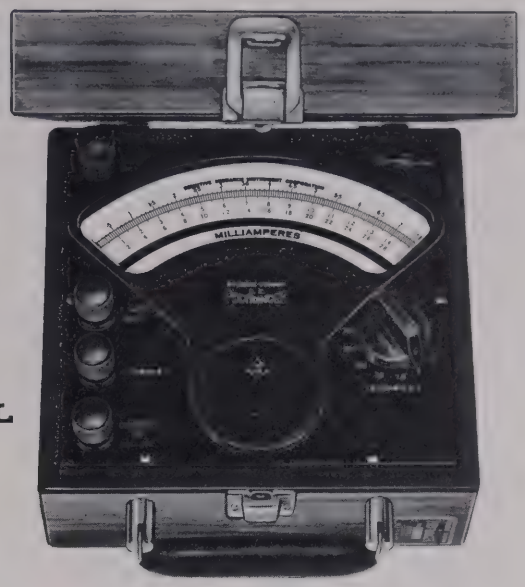
1. Voltage ranges can be extended by the addition of multipliers. (See Section 10.) If multipliers are ordered with the instrument, they can be calibrated together for an overall accuracy of .25% of full scale.

PANEL MOUNTED INSTRUMENTS

The Model C Polyranger is also available for vertical rack panel mounting. The indicator is housed in a Type EW-7A edgewise panel case with a 7" scale length, and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model. Specify as follows by listing the instrument range combination desired, plus the suffix "EW-7A."

Model:	1-CEW-7A	3-CEW-7A	4-CEW-7A
Price:	$420.00	$400.00	$400.00

MODEL C



GENERAL DESCRIPTION

The Model C is a 14 range DC reference standard indicating instrument similar in concept to the Model WVA (see page 162), but smaller in size and more economically priced. All .25% accurate instruments of this type, because of their stability and ruggedness, make excellent transfer devices between laboratory standards and small factory portables.

RANGES

COMBINATION 1-C — **Code RANGER** — **Price $345.00**

Current Ranges:	1	3	10	30	100	300 ma	1	3 amps
Approx. Resist:	54.5	72.8	27.6	9.8	3	1	.34	.1 Ω
*Voltage Ranges:	3	10	30	100	300	1000 v		

COMBINATION 3-C — **Code RANGOK** — **Price $325.00**

Current Ranges:	1.5	3	7.5	30	150	300	750 ma	3 amps
Approx. Resist:	43	86	50	14.3	3	1.5	.6	.15 Ω
*Voltage Ranges:	3	15	30	150	300	750 v		

COMBINATION 4-C — **Code RANGIS** — **Price $325.00**

Current Ranges:	10	50	100	500 ma	1	5	10 amps
Approx. Resist:	27.5	6	3	.6	.3	.06	.03 Ω
*Voltage Ranges:	1	5	10	50	100	500	1000 v

* Sensitivity of all Combinations 1000 Ω/v

Facsimile Model C Polyranger Scale (Comb. 3C)

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SENSITIVITY	Comb. 1-S: 1,000 Ω/v excepting 10,000 Ω/v on 5/10 mv ranges Comb. 2-S: 5,000 Ω/v all volt ranges Comb. 3-S: 10,000 Ω/v all volt ranges All current range resistances listed below.
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
SCALE DIVISIONS	100 divisions. Comb. 1-S & 3-S printed 0-.05/100; Comb. 2-S printed 0-.005/100
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled excepting 5 mv range on binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

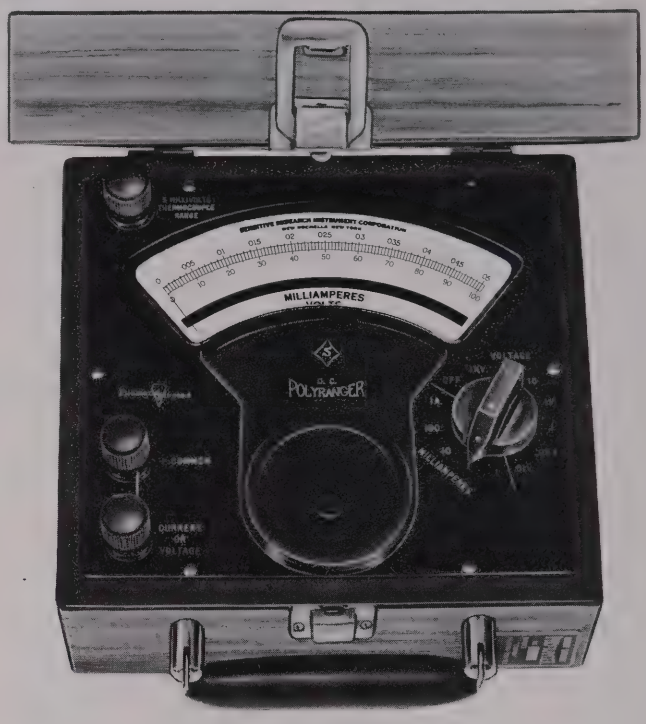
OPTIONAL ACCESSORIES

1. Ranges can be extended by the addition of shunts and multipliers. If ordered with the instrument, they can be calibrated together for an overall accuracy of .5% of full scale. RF measurements can be made by utilizing external vacuum thermocouples in conjunction with the 5 or 10 mv ranges. (Instrument accessories are described in Section 10.)

PANEL MOUNTED INSTRUMENTS

The Model S Polyranger is also available for rack panel mounting. The indicator is housed in a Type EW-5A edgewise panel case with a 5" scale length, and installed in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model. Specify as follows by listing the instrument range combination desired, plus the suffix "EW-5A."

Model:	1-SEW-5A	2-SEW-5A	3-SEW-5A
Price:	$410.00	$410.00	$493.00



GENERAL DESCRIPTION

The Model S Polyrangers are 13 range DC electrical indicating instruments designed for applications necessitating a high sensitivity reference standard. The "S" Polyranger is an ideal laboratory instrument in that it is capable of measuring over a broad range of values, and its insertion in a circuit is not likely to cause excessive loading.

COMBINATION 1-S **Code COMBO** **Price $335.00**

Current Ranges:	.1	1	10	100	1000 ma				
Approx. Resist:	50	90.5	9.45	1	1 Ω				
Voltage Ranges:	5	10	50	100 mv	1	10	100	1000 v	
Sensitivity:	1000 Ω/v except 5/10 mv ranges 10,000 Ω/v								

COMBINATION 2-S **Code COMBI** **Price $335.00**

Current Ranges:	.2	2	20	200	2000 ma				
Approx. Resist:	25	10	1.1	.11	.001 Ω				
Voltage Ranges:	5	10	20	100	200 mv	2	20	200 v	
Sensitivity:	All ranges 5000 Ω/v								

COMBINATION 3-S **Code COMBA** **Price $418.00**

Same ranges as Combination 1-S. All volt ranges 10,000 Ω/v

Facsimile Model S Polyranger Scale

GENERAL PURPOSE DC POLYRANGERS

The NPR and University Polyrangers described herein have been designed for applications where price, compatible with quality and reliability, is of prime importance. They have ranges that cover a broad area of DC measurements, while their size and configuration make them easily transported and read. **The Model NPR** features a 6.1" scale length giving it exceptional resolution for a low cost general purpose instrument. **The University Model** is a compact instrument with better than average sensitivity. All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL ACCESSORIES

1. Volt ranges can be extended by the addition of external multipliers. If ordered with the instruments, they can be calibrated for an overall accuracy of .5% of full scale.

2. Leather cases available. **Price: $30.00.**

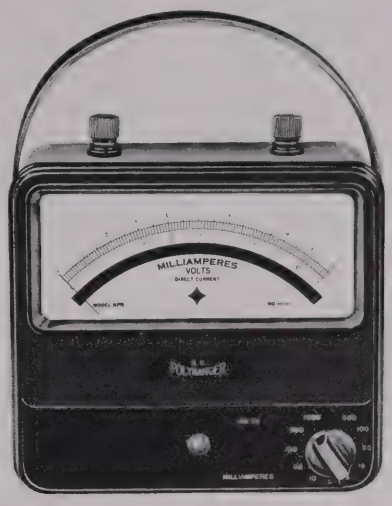
PANEL MOUNTED INSTRUMENTS

1. The Model NPR can be furnished for vertical flush panel mounting but must be specified at time of ordering. Additional price: $15.00. Terminals instead of switches can be substituted on request. Panel mounted instruments have polished high carbon steel pivots and solid jewels. When calibrated in the upright position, performance characteristics are the same as for the portable model excepting that the Comb. 1-NPR, Code NPRAIL has an accuracy of 1% of full scale.

2. The University Polyranger cannot be furnished for panel mounting. The models JW, JWSP and UPP described in Section 3 are compact DC panel instruments with equivalent performance specifications.

UNIVERSITY MODEL

MODEL NPR



SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
SCALE DIVISIONS	Comb. 1-UD: 100 divisions printed 0-10/20/500 Comb. 2-UD: 100 divisions printed 0-20/500
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Black moulded bakelite: 5 5/16" x 5 1/8" x 3 1/8" deep; carrying handle
APPROX. WEIGHT	4 1/2 lbs. net; 8 lbs. shipping

UNIVERSITY MODEL RANGES

COMBINATION 1-UD — **Code UCOMBIN** — **Price $215.00**

DC Current:	.1	1	10	100	1000 ma	
Approx. Resist:	1570	1570	178	18	1.8 Ω	
DC Voltage:	2	20	200	500 v		(1000 Ω/v)

COMBINATION 2-UD — **Code UCOMBON** — **Price $215.00**

DC Current:	.2	2	20	200	2000 ma	
Approx. Resist:	280	75	8.4	.85	.14 Ω	
DC Voltage:	2	20	200	500 v		(1000 Ω/v)

SPECIFICATIONS

Model NPR specifications same as University except as listed below.

SCALE	Hand-drawn; 6.1"; anti-parallax mirror
SCALE DIVISIONS	Comb. 1-NPR: 100 divisions printed 0-20/500 Comb. 2-NPR: 100 divisions printed 0-5/10 Comb. 3-NPR: 100 divisions printed 0-5/10
CASE	Moulded black bakelite; 7 1/2" x 6 15/16" x 3 3/8" deep; carrying handle
APPROX. WEIGHT	7 lbs. net; 10 lbs. shipping

MODEL NPR RANGES

COMBINATION 1-NPR — **Code NPRAIL** — **Price $265.00**

DC Current:	.2	2	20	200	2000 ma
Approx. Resist:	450	450	50	5	.5 Ω
DC Voltage:	2	20	200	500 v	(1000 Ω/v)

COMBINATION 2-NPR — **Code NPROST** — **Price $250.00**

DC Current:	1	5	10	100	500 ma
Approx. Resist:	210	320	200	20	4 Ω
DC Voltage:	5	10	50	100	500 v (1000 Ω/v)

COMBINATION 3-NPR — **Code NPREEL** — **Price $265.00**

DC Current:	5	10	50	100	500	1000 ma
Approx. Resist:	330	180	40	20	4	2 Ω
DC Voltage:	5	10	50	100	500 v	(1000 Ω/v)

DYNAMOMETER POLYRANGERS

SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	.3% of full scale
FREQUENCY	60 cps (50 cps optional)
TYPE	Transformer-coupled electrodynamometer
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
SCALE DIVISIONS	Comb. 1: 100/150 divisions printed 0-10/30 Comb. 2: 100 divisions printed 0-5/10/20
POINTER	Knife edge
PERIOD	4 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled excepting 10 amp range. In Comb. 2 only, 1,000 v on separate binding posts
MECHANICAL ZERO	External zero shifter
CASE	Formica: 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	10 lbs. net; 19 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. A 2000 v range can be supplied in Comb. 2. Additional price: $85.00.

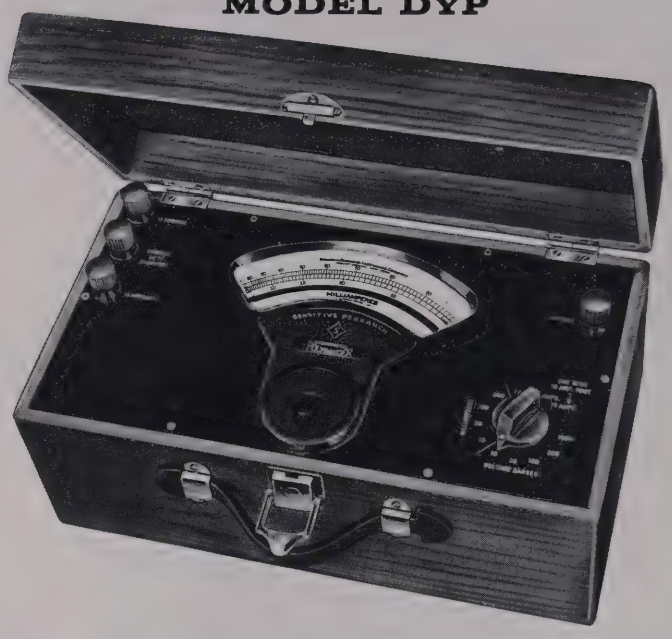
2. Transformers can be used to extend current ranges. The Model TR, Type 1 with a 5 amp secondary is recommended for use in conjunction wtih instrument ranges of 2 to 5 amps. (See Section 10.)

3. If specified, calibration can be at 50 cps at no extra charge.

PANEL MOUNTED INSTRUMENTS

The Model DYP is also available for vertical rack panel mounting. The indicator is housed in a Type EW-7A edgewise panel case with a 7" scale length, and mounted in a 19" x 7" x 5/16" black bakelite panel. Performance characteristics are the same as listed for the portable model. Specify as follows by listing the instrument range combination desired, plus the suffix "EW-7A."

MODEL DYP



Model:	1-DYPEW-7A	2-DYPEW-7A
Price:	$547.00	$641.00

GENERAL DESCRIPTION

The Model DYP is a transformer-coupled electrodynamometer instrument designed to cover a broad area of AC measurements at 60 cps. The Combination 1 has 12 ranges; the Combination 2, 20 ranges (with the optional 2000 v range). Range values are overlapping and all readings can be taken on the upper third of the scale for maximum accuracy. It is in this area of the scale that divisions are expanded and resolution is greatest. The Model DYP is unusual in that it offers all the advantages of a dynamometer movement in a Polyranger type instrument.

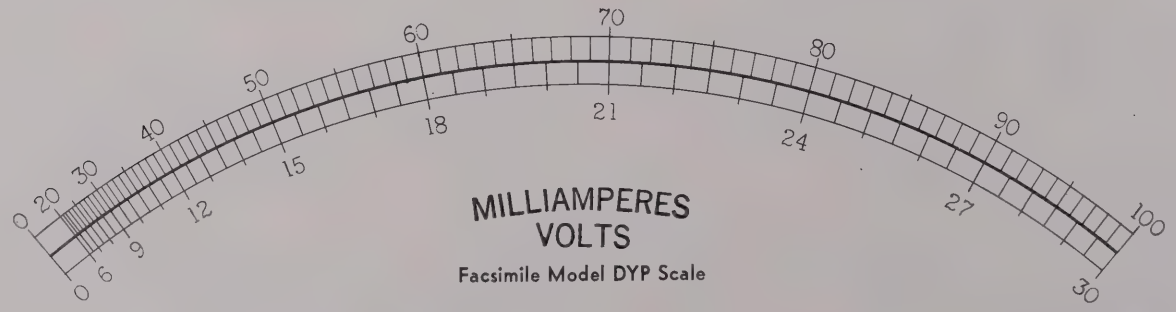
RANGES

COMBINATION 1 — **Code DYNAMO** — **Price $467.00**

AC Current:	10	30	100	300 ma	1	3	10	amps	
Approx. Burden (va):	1.4 va all current ranges								
AC Voltage:	10	30	100	300	1000 v				
Approx. Burden (va):	3	3	3	3	10 va				

COMBINATION 2 — **Code DYNOSP** — **Price $561.00**

AC Current:	5	10	20	50	100	200	500 ma	1	2	5	10 amps
Approx. Burden (va):	1.4 va all current ranges										
AC Voltage:	5	10	20	50	100	200	500	1000 v			
Approx. Burden (va):	2.5	5	4	5	5	4	5	10 va			



Facsimile Model DYP Scale

Prices and Specifications Subject to Change Without Notice

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MANUFACTURER'S REPRESENTATIVE
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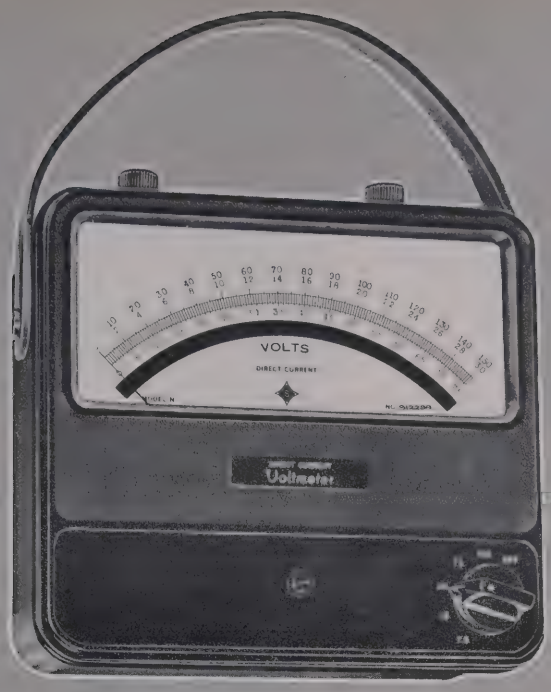
298-7573 DAYTON 29, O. 298-9857

MODEL N



MODEL JW-4A

Portable and Panel

DIRECT CURRENT PERMANENT MAGNET, MOVING COIL

MICROAMMETERS, MILLIAMMETERS, AMMETERS, MILLIVOLTMETERS, VOLTMETERS, KILOVOLTMETERS, UNIVERSAL DC TEST SET

Model	Description	Page
C	.25% Reference Standard Microammeters, Milliammeters, Ammeters, Millivoltmeters, Voltmeters. 6.3" scale length	202-203
S	.5% High Sensitivity Microammeters, Milliammeters, Millivoltmeters and Voltmeters. 6.3" scale length	204-205
HS	.5% Ultra-high Sensitivity Millivolt-Voltmeters. 6.3" scale length	206
N	.25% and .5% Microammeters, Milliammeters, Ammeters, Millivoltmeters and Voltmeters. 6.1" scale length	207-208
NP	.5% Rectangular Panel Microammeters, Milliammeters, Ammeters, Millivoltmeters, Voltmeters. 6.1" scale length	208-209
University	.5% Microammeters, Milliammeters, Ammeters, Millivoltmeters, Voltmeters. 4" scale length	210-211
DCHI	.5% and 1% High Sensitivity Kilovoltmeters. 4" scale length	212
J	.5% High Sensitivity Bench Type Calibrated Galvanometers. 3.25" scale length	213
UPP	.5% and 1% Rectangular Panel Microammeters, Milliammeters, Ammeters, Millivoltmeters, and Voltmeters. 4" scale length	214-215
JW-4A	.5% Edgewise Panel Microammeters, Milliammeters, Ammeters, Millivoltmeters, and Voltmeters. 4" scale length	216-217
JWSP	.5% Edgewise Panel Microammeters, Milliammeters, Ammeters, Millivoltmeters, Voltmeters. 4" scale length	217
UTS	.5% Portable DC Test Set to Measure Current, Voltage and Resistance	218-219
	Mounting dimensions: (1) Edgewise panel instruments in Type EW-5A and EW-7A shallow cases, (2) Models JW-4A, JWSP and NP, (Model UPP see page 215)	220

Prices and specifications subject to change without notice. *Terms net 30 days F.O.B. New Rochelle, N. Y.*

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

Electrical Measuring Instruments Since 1927

MODEL C REFERENCE STANDARD INSTRUMENTS

MICROAMMETERS, MILLIAMMETERS, AMMETERS, MILLIVOLTMETERS & VOLTMETERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Multirange instruments switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model C conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. Instruments with special scales and/or ranges available. Multirange instruments are normally switch controlled to 3 amperes and 1000 volts (500 volts maximum between switch positions). Voltmeters can be supplied with sensitivities as high as 20,000 ohms per volt. Correspondence required on all special instruments.

2. Instruments can be furnished with specially designed automatic or manually operated electrical overload protection. Correspondence required.

3. "Zero Center" instruments can be supplied at no extra charge. Accuracy is rated in percentage of the sum of the right and left full scale values (Example: Ranges, 5 ma-0-5 ma; accuracy, ± .25% of 10 ma or ± .025 ma any place on the scale).

PANEL INSTRUMENTS

The Model C is also available for vertical panel mounting in the shallow EW-7A (7" scale length) or EW-5A (5" scale length) edgewise panel case. The EW-7A is recommended for this model because of its greater scale length. For dimensions see page 220.

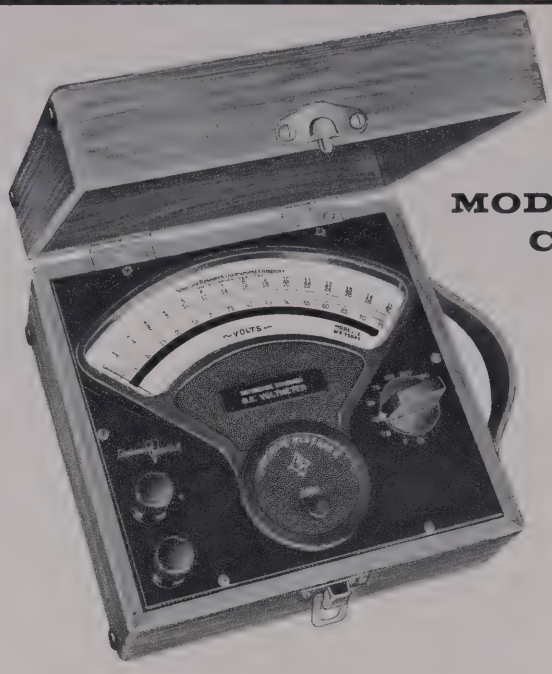
Performance characteristics are the same as listed for the portable type, except as follows:

a) Multirange instruments can have a maximum of 8 ranges switch controlled (only 7 ranges if either a "Short" or "Off" position is desired); the remainder are supplied on terminals. In such cases, unless otherwise specified, highest ranges are supplied on terminals.

b) Type EW-5A cased instruments are limited to a maximum of 100 scale divisions.

Specify: Model CEW-7A or CEW-5A and code word of portable instrument having ranges desired. Specify sensitivity (ohms per volt) of voltmeters.

Price: Add $25.00 to price of code word selected.



MODEL C

GENERAL DESCRIPTION

The design of the Model C incorporates all of the qualities associated with the term "Reference Standard," particularly as to accuracy, ruggedness and response time. Special attention has been given to provide a mechanically outstanding moving system. The pointer is made of tubular aluminum and assembled in three sections for minimum weight and maximum strength. Strong restoring springs are combined with a light weight self-supporting coil to provide an unusually high torque-to-weight ratio. The assembly is diamond pivoted and set in shock mounted sapphire jewels to give a virtually friction free moving element.

A magnetic shield is used as an integral part of the instrument case. Unlike instruments with wrap-around shields or core magnets with self shielding polepieces, it subtracts very little from the magnetic field and is not a factor in scale linearity when a moving coil has to be removed and replaced. Its presence adds to the rigidity and dimensional stability of the case which is made of tough, durable formica and gasketed to provide an effective dust and humidity barrier.

When ordering voltmeters, ohms per volt must be specified, since most instruments are available with a choice of more than one sensitivity.

The long term stability and repeatability of the Model C finds direct application for those desiring an accurate transfer standard between laboratory standards and production or field instrumentation. As an edgewise panel instrument, it fills the ever-increasing need for greater accuracy in production-line testing and OEM applications.

MICROAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
30	7,000	150	CICIK	$200.00
50	5,800	100	CICAM	195.00
100	2,800	100	CICOL	190.00
200	800	100	CICMO	190.00
500	100	100	CICET	190.00

MODEL C REFERENCE STANDARD INSTRUMENTS

MICROAMMETERS, MILLIAMMETERS, AMMETERS, MILLIVOLTMETERS & VOLTMETERS

MULTIRANGE MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
.05/.1/.5/1/5/10/50/100	6200/16700/5460/2860/594/298/60/30	100	CILKI	$288.00
1.5/7.5/30/150	88/123/36/7.5	150	CILBRA	237.00
3/15/75/150	45/82/20/10	150	CILCOT	237.00
5/10/50/200	44/98/32/9	100	CILDEN	237.00
10/50/200/500	13/17/4.7/1.9	100	CILENT	237.00
15/75/300/750	11/8.4/2.5/1	150	CILFOR	237.00
50/200/500/1000	2.2/.7/.5/.3	100	CILHAT	237.00
150/300/750/1500	2/1/.4/.2	150	CILIST	237.00

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1.5/3/7.5/15/30/75/150/300/750/1500	88/210/123/72/36/15/7.4/3.7/1.5/.75	150	CILPOL	293.00
2/5/10/20/50/100/200/500/1000	86/158/99/55/23/12/6/2.4/1.2	100	CILMUL	283.00

SINGLE RANGE MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	100	100	CILEL	$175.00
3	70	150	CILIP	175.00
5	30	100	CILOP	175.00
7.5	15	150	CILUK	175.00
10	6	100	CILAS	175.00
15	5	150	CILTO	175.00
30	3	150	CILKY	175.00
50	1.5	100	CILCA	175.00
100	.50	100	CILDI	175.00
200	.25	100	CILFO	175.00
300	.15	150	CILHU	175.00
500	.10	100	CILLE	175.00
750	.05	150	CILPY	175.00

AMMETERS

Any single range ammeter with ranges from 1 amp to 7.5 amps, price $182.00; above 7.5 amps to 20 amps, price $187.00; above 20 amps to 50 amps, price $195.00.

Ammeters are supplied self contained. Ranges of 20 amperes and higher have their shunts attached to rear of the case.

MILLIVOLTMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
50	12.5	100 or 150	CMVTA	$190.00
100	25		CMVTU	190.00
50/100	12.5/25		CMVPO	202.00

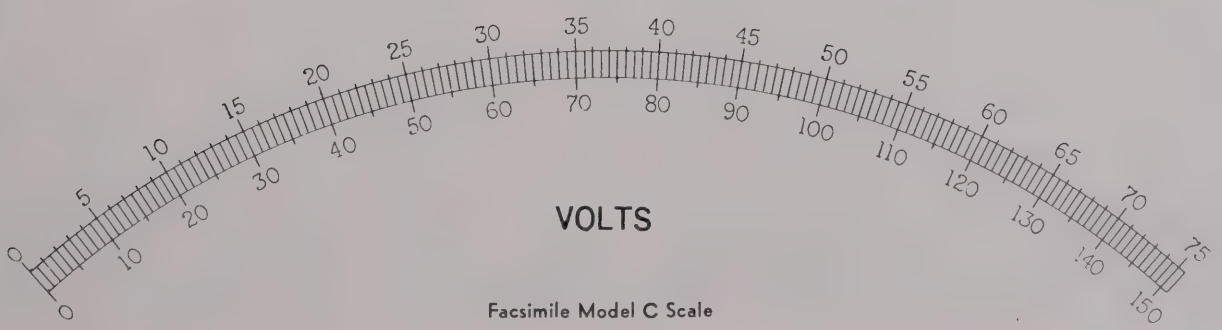
Calibrated and supplied with a pair of 5′, .026 ohm leads. Current shunts listed in Section 10. Millivoltmeter and current shunts ordered at the same time can be calibrated together to be within the accuracy of the instrument. If specified, at no extra charge, calibration can be at terminals of millivoltmeter. Normally supplied with scales printed in "millivolts" unless ordered otherwise.

Instruments can be furnished at no extra charge with scales marked "Amperes" and 100 or 150 divisions. Specify numerals desired and scale divisions when ordering. A double scale printed 0-100, 0-150 is available; add $20.00 to price. For extra rows of numerals add $5.00 per row, four rows maximum.

VOLTMETERS

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1	100	COLED	$176.00	$186.00
3	150	COLOG	176.00	186.00
10	100	COLBA	176.00	186.00
15	150	COLJY	176.00	186.00
50	100	COLFU	180.00	200.00
100	100	COLGY	182.00	202.00
150	150	COLHO	185.00	205.00
300	150	COLKI	190.00	210.00
500	100	COLLY	193.00	213.00
750	150	COLMO	196.00	218.00
1000	100	COLNI	200.00	222.00
1500	150	COLPA	206.00	231.00
1.5/7.5/30/150	150	COLRA	232.00	242.00
2/10/50/200	100	COLST	232.00	242.00
3/15/75/300	150	COLTO	235.00	245.00
5/20/100/500	100	COLVY	240.00	252.00
10/50/200/500	100	COLWU	240.00	252.00
15/75/300/750	150	COLZO	247.00	262.00

Range	Scale Div.	Code	Price 1000 Ω/v
1.5/3/7.5/15/30/75/150/300/750	150	COLPOL	302.00
2/5/10/20/50/100/200/500/1000	100	COLMUL	307.00



Facsimile Model C Scale

MODEL S HIGH SENSITIVITY INSTRUMENTS

MICROAMMETERS, MILLIAMMETERS, MILLIVOLTMETERS AND VOLTMETERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale; 1% accuracy on ranges below 5μa
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Multirange instruments switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model S conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. Instruments with special scales and/or ranges available. Multirange instruments are normally switch controlled to 3 amperes and 1000 volts (500 volts maximum between switch positions). Voltmeters can be supplied with sensitivities as high as 50,000 ohms per volt (see models HS and DCHI, described in this bulletin, for higher sensitivities). When specifying current instruments with special ranges, indicate whether high or low resistance design is desired. Correspondence is required on all special instruments.

2. Instruments can be furnished with specially designed automatic or manual electrical overload protection. Correspondence required.

3. "Zero Center" instruments can be supplied at no extra charge. Accuracy is rated in percentage of the sum of the right and left full scale values. (Example: Range, 5 ma-0-5 ma; accuracy, ±.5% of 10 ma, or ±.05 ma any place on the scale)

PANEL INSTRUMENTS

The Model S is also available for vertical panel mounting in the shallow EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 220.

Performance characteristics are the same as listed for the portable type, except as follows:

a. High resistance microammeters with ranges of 5 microamps or less and low resistance microammeters with ranges of 15 microamps or less have a 5.2" scale when supplied in a Type EW-7A case.

b. Multirange instruments can have a maximum of 8 ranges switch controlled (only 7 ranges if either a "Short" or an "Off" position is desired); the remainder must be supplied on terminals. In such cases, unless otherwise specified, the highest ranges are supplied on terminals.

c. Type EW-5A cased instruments are limited to a maximum of 100 scale divisions.

MULTIRANGE VOLTMETERS

Range	Scale Div.	Code	Price
1.5/3/7.5/15/30/75/150/300/750	150	SOLBEK	$325.00
2/5/10/20/50/100/200/500	100	SOLCAK	325.00
10/50/100/200/500/1000	100	SOLDOK	325.00
15/30/75/150/300/750/1500	150	SOLFAP	345.00

Sensitivity 10,000 ohms per volt

MODEL S

GENERAL DESCRIPTION

The Model S instruments comprise a de luxe line of sturdy "high sensitivity" microammeters, milliammeters, millivoltmeters and voltmeters. Special consideration is given to natural aging time to ensure permanent stability. The construction of the moving element is of the same superb quality as that of the Model C described on page 202.

Microammeters and milliammeters are available as either "High" or "Low" resistance designs. Low Resistance current measuring instruments and High Resistance voltage measuring instruments are more electrically efficient and, therefore, usable in a circuit where only a minimum amount of energy is available. The High Resistance type has a faster period, is more rugged and, therefore, except in circuits requiring extremely high sensitivity, should be selected instead of the Low Resistance type.

All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases are made of tough, durable formica and are gasketed to provide an effective dust and humidity barrier. For flexibility the multirange instrument is the ideal selection. In the construction of multirange high sensitivity current measuring instruments, a ring type shunt is used to achieve uniform damping and a satisfactory temperature coefficient. This shunt is usually ten or more times the resistance of the moving element and will very often cause the second and third lowest ranges to have a higher resistance than the most sensitive range.

When ordering voltmeters, ohms per volt must be specified since most instruments are available with a choice of more than one sensitivity.

SINGLE RANGE VOLTMETERS

Range	Scale Div.	Code	Price 1000 Ω/v	5000 Ω/v	10,000 Ω/v	20,000 Ω/v	50,000 Ω/v
.5	100	SOLVA	$170.00	$180.00	$190.00	$200.00	$210.00
1.5	150	SOLAK	170.00	180.00	190.00	200.00	210.00
3	150	SOLEM	170.00	180.00	190.00	200.00	210.00
10	100	SOLIT	170.00	180.00	190.00	200.00	210.00
30	150	SOLOR	172.00	185.00	200.00	210.00	215.00
50	100	SOLUS	175.00	195.00	205.00	225.00	230.00
150	150	SOLKA	180.00	200.00	215.00	230.00	——
300	150	SOLDA	185.00	205.00	222.00	——	——
750	150	SOLDU	190.00	212.00	232.00	——	——
1500	150	SOLBI	200.00	225.00	255.00	——	——

NOTE: Specify ohms per volt when ordering.

ADDITIONAL SPECIFICATIONS FOR MILLIVOLTMETERS

a. All millivoltmeters with ranges below 50 mv are calibrated and supplied with a pair of 5', .026 ohm leads. Calibration can be made at the instrument's terminals at no extra charge if specified.

b. The codes SMVVO and SMVBU, are recommended for use with current shunts. (See Section 10.)

c. Instruments with ranges of 10 mv or less are recommended for use with vacuum thermocouples. (See Section 10.) Attention is specifically called to the Code SMVLA listed at right, which has a constant 10 Ω resistance for ranges of 3/10 mv.

d. Millivoltmeters are normally furnished with scales calibrated and printed in millivolts, but on special order they can be supplied having a different legend, such as "Amperes" at no extra charge. In such a case, the user has a choice of either a 100 or 150 division scale and a single row of numerals. For each extra row of numerals specified (maximum 4 rows) add $5.00. For a double scale of 100 and 150 divisions and two rows of printing add $20.00.

e. All instruments have automatic temperature compensation between 20°C and 30°C.

MILLIVOLTMETERS

Range	Approx. Ω/mv	Scale Div.	Code	Price
1	5	100	SMVMA	$210.00
2	5	100	SMVPU	195.00
5	5	100	SMVSI	195.00
10	5	100	SMVTA	195.00
50	5	100	SMVVO	185.00
100	5	100	SMVBU	185.00
2/5	5	100	SMVZO	215.00
1/5/20/50	5	100	SMVLE	252.00
1/10/100/1000	5	100	SMVLI	252.00
1.5/7.5/15/30/75	5	150	SMVLO	257.00
2/5/10/20/50/100	5	100	SMVLU	275.00
2/20/200/2000	5	100	SMVLY	252.00
3/10	10 Ω both ranges	150/100	SMVLA	245.00

CONSTANT RESISTANCE MICROAMMETERS

Range	Resist. all ranges Ω	Scale Div.	Code	Price
20/50/100/200/500/1000 μa	1050	100	PHORCA	$346.00
50/100/200/500/1000 μa	100	100	PHOTOX	330.00
200 μa/2/20/200ma	10	100	PHOLUV	294.00

5.2" scale length

MICROAMMETERS

HIGH RESISTANCE DESIGN

Ranges below 5 microamperes have a 5.2" scale length and an accuracy of 1%.

Range	Approx. Resist. Ω	Scale Div.	Code	Price
*1.5	7200	75	SXICAII	$280.00
*2	7200	100	SXICOTA	245.00
5	6900	100	SXICAMP	225.00
10	6900	100	SXICENT	185.00
15	6900	150	SXICILO	180.00
20	2000	100	SXICOPT	180.00
30	1800	150	SXICROT	175.00
50	900	100	SXICAPS	175.00
100	700	100	SXICERO	165.00
150	235	150	SXICIKA	165.00
200	100	100	SXICORT	165.00
300	50	150	SXICUBE	165.00
500	50	100	SXICADE	165.00
1000	40	100	SXICEKT	165.00
*2.5/10/50	6900/135000/28500	125/100	SXICTO	284.00
* 3/15/75	6900/80400/18200	60/75	SXICDA	274.00
* 3/30/300	6900/45100/4950	60	SXICHI	274.00
5/20/100	6800/75700/19000	100	SXICJO	261.00
5/50/500	6800/32200/3960	100	SXICKU	261.00
10/50/100	5600/32250/19050	100	SXICLA	223.00
10/100/1000	5600/18050/1980	100	SXICMI	223.00

LOW RESISTANCE DESIGN

Ranges of 15 microamperes or under have a 5.2" scale length. Ranges below 5 microamperes have an accuracy of 1%.

Approx. Resist. Ω	Code	Price
6500	SICOTA	$270.00
3000	SICAMP	250.00
3000	SICENT	235.00
2600	SICILO	230.00
280	SICOPT	230.00
180	SICROT	225.00
100	SICAPS	225.00
50	SICERO	215.00
30	SICIKA	215.00
10	SICORT	215.00
7.5	SICUBE	215.00
5	SICADE	215.00
2	SICEKT	215.00
*5800/48000/11600	SICDA	297.00
*5800/22600/2370	SICHI	297.00
4800/28000/7000	SICJO	291.00
4800/13500/1480	SICKU	291.00
2500/6500/3630	SICLA	276.00
2500/3630/396	SICMI	276.00

MULTIRANGE MILLIAMMETERS

(M = 1000Ω)

HIGH RESISTANCE DESIGN

Range	Approx. Resist. Ω	Scale Div.	Code	Price
*.0025/.005/.01/.025/.05/.1/.5/1	6900/153M/135M/54M/28.5M/14650/2985/1500	125/100	SXILSA	$351.00
*.003/.03/.3/3/30	6900/45100/4950/500/50	60	SXILBO	309.00
*.004/.04/.4/4/40	6900/36600/3960/398/40	80	SXILCU	303.00
.005/.02/.1/.5/2/10	6800/75700/19000/3960/998/200	100	SXILDA	303.00
.01/.05/.1/.5/1/5/10/50	5600/32250/18000/3925/1980/400/200/40	100	SXILFI	285.00
.01/.1/1/10/100/1000	5000/18000/1980/200/20/2	100	SXILIT	265.00
.02/.2/2/20/200	2500/5425/594/60/6	100	SXILKA	241.00
.03/.3/3/30/300	1300/3630/396/40/4	150	SXILMO	241.00
.05/.1/.5/1/5/10/50/100	1200/3750/1350/750/150/75/15/7.5	100	SXILNI	275.00
.05/.5/5/50/500	1200/1350/150/15/1.5	100	SXILOT	241.00
.1/1/10/100/1000	900/495/55/5.5/.55	100	SXILPU	241.00
.1/.5/1/5/10/50/100/500	900/900/500/110/55/11/5.5/1.1	100	SXILRA	275.00
.2/2/20/200	85/37/3.9/.4	100	SXILUV	231.00
.5/5/50/500	45/27/2.5/.3	100	SXILIV	231.00
.5/2/10/50/200/1000	45/60/14/3/.75/.15	100	SXILXY	247.00

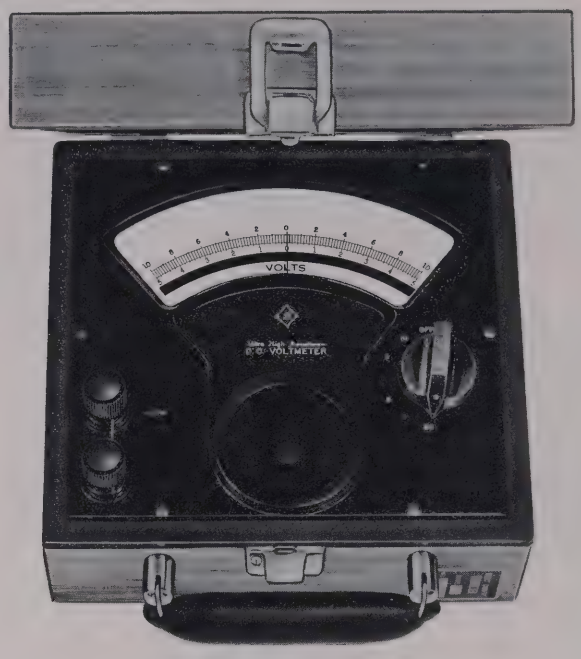
LOW RESISTANCE DESIGN

Approx. Resist. Ω	Code	Price
5800/22600/2370/240/24	SILBO	$332.00
4800/9059/990/100/10	SILCU	326.00
3000/28000/7000/1400/375/75	SILDA	326.00
2500/6510/3630/785/396/80/40/8	SILFI	328.00
2500/3630/396/40/4/.4	SILIT	308.00
800/1000/109/11/1.1	SILKA	289.00
800/1000/109/11/1.1	SILMO	289.00
250/1250/450/250/50/25/5/2.5	SILNI	325.00
210/450/50/5/.5	SILOT	289.00
50/50/5.5/.55/.055	SILPU	289.00
50/90/50/11/5.5/1.1/.55/.11	SILRA	325.00
10/10/1.1/1.1	SILUV	294.00
10/10/1.1/.11	SILIV	279.00
10/21/5.2/1.1/.27/.055	SILXY	295.00

*Not magnetically shielded.

MODEL HS ULTRA HIGH SENSITIVITY MILLIVOLT-VOLTMETERS

MODEL HS



SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale for sensitivities of 200,000 Ω/v and less; 1% for sensitivities above 200,000 Ω/v
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model HS conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. Instruments with special ranges and/or scales available. Correspondence required.

2. Instruments can be furnished with specially designed electrical overload protection. Correspondence required.

3. A polarity reversing switch can be installed at an additional cost of $25.00.

4. Any "Zero Left" instrument can also be obtained with a "Zero Center" at no additional charge.

PANEL INSTRUMENTS

The Model HS is also available for vertical panel mounting in the shallow EW-5A (5″ scale length) or EW-7A (7″ scale length) edgewise case. Dimensions on page 220.

Performance characteristics are the same as listed for the portable type, except as follows:

a. 200,000 Ω/v is the highest available sensitivity for panel mounting. The combination of ohms per volt and highest range cannot exceed a total instrument resistance of 10 megohms.

b. Polarity reversing switch not available internally.

c. A maximum of 8 ranges (only 7 ranges, if a "Short" or "Off" position is desired), can be furnished switch controlled. Unless otherwise specified, highest volt ranges are placed on binding posts when this figure is exceeded.

Specify: Model HSEW-5A or HSEW-7A, code word and sensitivity of portable instrument having ranges desired.

Price: Add $25.00 to price of code word selected.

SPECIAL "ZERO CENTER" VOLTMETERS

Range	Code	Price
.0005/.002/.005/.02/.05/.2/.5/2/5/20/50/200	SOLSEN	$395.00
Sensitivity: approx. 10,000 Ω/v all ranges.		
*.001/.0025/.005/.01/.025/.05/.1/.25/.5/1/2.5	AMWEST	530.00
Sensitivity: approx. 10,000 Ω/v on 1/2.5/10 mv ranges. All other ranges approx. 200,000 Ω/v.		

Calibrated and supplied with 5′, .026Ω leads. Instruments have 50-0-50 scale divisions.

GENERAL DESCRIPTION

The Model HS instruments listed below are ultra-high sensitivity DC Voltmeters similar in design to the Model S described on pages 204-205. Input resistances as high as 1,000,000 ohms per volt make them particularly suitable for corrosion and electrolysis measurements. All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases, made of tough durable formica, are gasketed to provide an effective dust and humidity barrier.

Where current cannot be drawn from a circuit, potentiometric instruments are recommended such as the Model PC, "PocketPot," described in Section 1, and the Model PV, Potentiometer Voltmeter, described in Section 9. For high sensitivity kilovolt measurements refer to the Model DCHI listed on page 212, and to Section 6 describing AC/DC Electrostatic Voltmeters.

Accuracy of "Zero Center" instruments is defined as the percentage of the sum of the right and left full scale values. (Example: Ranges 5v-0-5v; accuracy ±.5% of 10 v or ±.05 v any place on the scale.)

"ZERO LEFT" VOLTMETERS

Range	Ω/v	Code	Price
.005/.02/.1/.5/2/5/20/50/100	10,000	HIVOTO	$317.00
.02/.05/.1/.2/1/5/20/50	50,000	HIVOSP	326.00
.05/.1/.5/1/5/10	100,000	HIVOOM	333.00
	200,000	HIVOOM-2	348.00
	*500,000	HIVOOM-5	359.00

All instruments have 100 scale divisions.

"ZERO CENTER" VOLTMETERS

Range	Ω/v	Code	Price
.005/.025/.1/.5/2.5/ 5/25/50/100	20,000	HIZOR	$317.00
.025/.05/.1/.25/1/5/10	200,000	HIZOX	338.00
.05/.1/.5/1/5/10	200,000	HIZOZA	338.00
	*500,000	HIZOZA-5	343.00
	*1,000,000	HIZOZA-10	369.00

All instruments have 50-0-50 scale divisions.
*5.2″ scale length, not magnetically shielded.

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale (.25% optional, see below)
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 6.1"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Polished high carbon steel
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts (switch optional, see below)
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 7½" x 6 15/16" x 3⅜" deep; carrying handle
APPROX. WEIGHT	6 lbs. net; 9 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model N conforms to the following specifications: ASA C-39.1 and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. Any Model N can also be supplied with an accuracy of .25% at an additional charge of $15.00. Specify and add the suffix "-X" to the proper code word.

2. Multirange instruments are available with 5 switch controlled ranges (6 ranges if "Short" or "Off" position is omitted) to 2 amperes and 1000 volts. A maximum of 500 volts is allowable between switch positions. Additional cost of switch is $10.00.

3. Special ranges and/or scales available on special order.

4. "Zero Center" instruments are available at no additional charge. Accuracy is defined as the percentage of the sum of the left and right full scale values.

5. Diamond pivoted instruments available at an additional charge of $30.00.

6. Instruments can be furnished with specially designed manual or automatic electrical overload protection. Correspondence required.

GENERAL DESCRIPTION

The Model N comprises a new series of portable current and voltage indicating instruments. Its design represents a practical compromise between the de luxe Model C Reference Standard (see pages 202-203), and the compact, economy priced, high resistance type University Model (see pages 210-211). It employs a full size permanent magnet and large moving coil not ordinarily found in instruments in its price class and, therefore, has an unusually high torque-to-weight ratio. Strong restoring springs assure excellent precision, ruggedness, negligible position influence and a fast response time. These qualities and a 6.1" scale length, which provides exceptional resolution, enable it to be offered as a low cost, .25% accurate reference standard if a normal .5% accuracy is not sufficient.

The resistors and wiring network of the instrument are easily accessible for maintenance purposes. The moving element is placed in a separate compartment. Resistors are mounted in a ventilated insulated location.

The Model NSI is a companion .5% accurate AC indicating instrument. It is described in Section 4.

MODEL N

PANEL MOUNTING

The Model NP (pages 208-209) is a .5% accurate DC panel instrument with the same dimensions as the Model N.

MICROAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
50	3000	100	NICAMS	$131.00
100	950	100	NICENT	131.00
200	900	100	NICIPO	131.00
500	450	100	NICOLA	131.00
Any single range microammeter from 50 microamperes, Price $131.00				
50/500/5000	1500/1500/150	100	NICUXE	$151.00
50/100/200/500/1000	1500/7000/3100/1500/750	100	NICYUM	171.00
75/150/300/750/1500	1200/2500/2200/900/450	150	NICERO	171.00

MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	90	100	NILABI	$125.00
10	20	100	NILOFS	125.00
50	2	100	NILOOM	125.00
100	1	100	NILOUT	125.00
500	.15	100	NILAAM	125.00
Any single range milliammeter from 1 milliampere, Price $125.00				
.1/1/10		100	NILEBT	$147.00
1/5/20		100	NILICA	147.00
1.5/7.5/30		150	NILODD	141.00
3/15/75		150	NILUEF	141.00
15/150/1500		150	NILIMO	141.00
30/300/3000		150	NILONI	141.00
75/150/300		150	NILUTH	141.00
1/10/100/1000		100	NILEGT	149.00
1/2/5/10/20		100	NILAFS	157.00
1.5/3/7.5/15/30		150	NILIJU	157.00
5/10/20/50/100		100	NILUKL	157.00
10/50/100/500/1000		100	NILELY	157.00
20/50/100/200/500		100	NILOIV	157.00
75/150/300/750/1500		150	NILARZ	157.00

AMMETERS

Any single range ammeter from 1 amp to 10 amps, price $129.00
Above 10 amps to 50 amps, price $133.00

Range	Scale Div.	Code	Price
.05/.5/5	100	NAMMUK	$143.00
.1/1/10	100	NAMMAC	143.00
.5/1/2	100	NAMMAH	143.00
1/2/5	100	NAMMEN	143.00
1.5/3/15	150	NAMNIF	143.00
3/15/30	150	NAMMUJ	143.00
5/10/20	100	NAMMIZ	143.00
10/20/50	100	NAMMOI	143.00
1.5/3/7.5/15	150	NAMMRE	158.00
1/2/5/10/20	100	NAMMOY	173.00

Shunts are self contained.

MODEL NP RECTANGULAR PANEL INSTRUMENTS

MILLIVOLTMETERS

All millivoltmeters supplied and calibrated with a pair of 5', .026 ohm leads. Calibration, if specified, can be at the instrument's terminals. They normally contain a 100 division scale labeled "Millivolts." A 150 division scale and/or the legend "Amperes" can be substituted at no extra charge. A double scale can be drawn at an additional cost of $15.00. The scale plate can have a maximum of 4 rows of numerals. Each set of divisions is normally furnished with a single row of printed numerals. Additional rows are $5.00 each.

Range	Scale Div.	Code	Approx. Ω/mv	Price
50	100	NIMIVA	1	$131.00
Any single range millivoltmeter from 20 millivolts, price $131.00.				
50/100	100	NIMIVOL	1	146.00
20/50/100	100	NIMIVAK	1	154.00
20/50/100/200/500	100	NIMIVEL	1	169.00
20/50/200/500/2000	100	NIMIVUP	1	169.00

VOLTMETERS

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5	150	NIVOLT	$128.00	$138.00
150	150	NIVOCU	128.00	138.00
750	150	NIVOSH	135.00	145.00
1000	100	NIVOTZ	135.00	145.00
3/15/150	150	NIVOHO	142.00	152.00
5/50/500	100	NIVOUX	142.00	152.00
150/300/750	150	NIVORG	152.00	162.00
200/500/1000	100	NIVOPI	152.00	162.00
7.5/15/30/75	150	NIVOLK	152.00	162.00
75/150/300/750	150	NIVONS	162.00	172.00
*3/15/75/300/1500	150	NIVOVE	183.00	193.00
50/100/200/500/1000	100	NIVOWL	178.00	188.00

*1500 v range cannot be switch controlled.

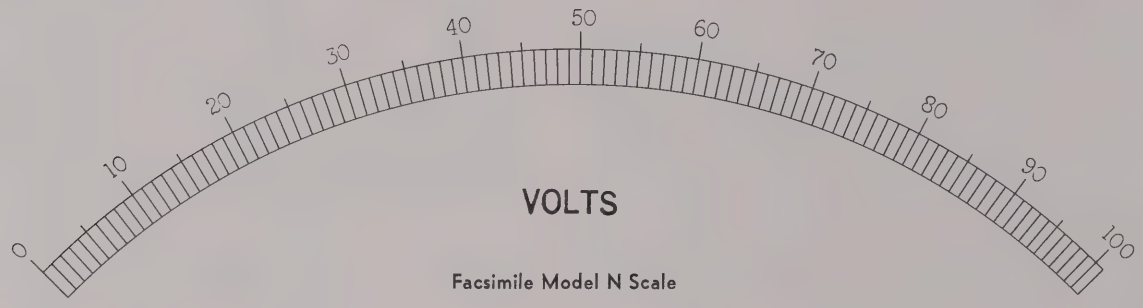
Note: It is impossible to list all combinations of volt ranges because of space limitations. The following information is pertinent to the selection of special volt ranges. Prices based on 1000 Ω/v. Add $10.00 for 5000 Ω/v.

A. Any single range from 1 v to 500 v, price $128.00. Any single range over 500 v to 1000 v, price $135.00.

B. Any three ranges (requiring 1 set of scale divisions) from 1 v to 500 v, price $142.00; where 1 or more ranges is over 500 v to 1000 v, price $152.00.

C. Any four ranges (requiring 1 set of scale divisions) from 1 v to 500 v, price $152.00; where 1 or more ranges is over 500 v to 1000 v, price $162.00.

D. If special ranges requested need an additional set of scale divisions for good readability, add $15.00.



Facsimile Model N Scale

SPECIFICATIONS

DC RECTANGULAR PANEL INSTRUMENT

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 6.1"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Polished high carbon steel
JEWELS	Sapphire
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts (switch optional, see below)
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 7½" x 6 15/16" x 3⅜" deep (See mounting dimensions, page 220.)
APPROX. WEIGHT	6 lbs. net; 9 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model NP conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

MODEL NP

MODEL NP RECTANGULAR PANEL INSTRUMENTS

OPTIONAL SPECIFICATIONS

1. Lance type pointers and/or heavier scale markings can be furnished at no extra charge if specified.
2. Multirange instruments are available with 5 switch controlled ranges (6 ranges if "Short" or "Off" position is omitted) to 2 amperes and 1000 volts. A maximum of 500 volts is allowable between switch positions. Additional cost of switch is $10.00.
3. Special ranges and/or scales available.
4. "Zero Center" instruments are available at no additional charge. Accuracy is defined as the sum of the left and right full scale values.
5. Instruments can be furnished with specially designed manual or automatic electrical overload protection. Correspondence required.
6. Internal illumination can be supplied at a cost of $24.00.

Note: The Model NP is not available with diamond pivots and spring mounted jewels unless it is to be mounted in a horizontal panel. In such cases specify and add $30.00 to price.

GENERAL DESCRIPTION

The Model NP is designed with special emphasis on torque-to-weight ratio. *It has extremely strong restoring springs and consequently experiences no difficulty with zero return, repeatability and balance.* Magnetic shielding is well within ASA specifications. However, as an additional service, at no extra charge, if a series of instruments are to be mounted in close proximity to each other, they can be calibrated duplicating their exact operating positions.

The Model NP is identical in design to the portable Model N described on the preceding pages except that it is made for operation in a vertical panel and is not offered in all the same ranges and sensitivities. It is normally supplied for flush mounting but if specified can be furnished for projection mounting at no extra charge.

MICROAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
200	5400	100	NPICOS	$131.00
300	2800	150	NPICAB	131.00
500	700	100	NPICUL	131.00
750	200	150	NPICER	131.00

Any single range microammeter from 200 microamperes, price $131.00.

200/500/1000	6000/13000/9000	100	NPICOO	151.00
300/750/1500	3000/6500/4000	150	NPICULY	151.00
500/1000/2000	700/2000/500	100	NPICRY	151.00
200/500 μa 1/2/5 ma	6M/13M/9M/5M/2M	100	NPICCE	171.00
300/750 μa 1.5/3/7.5 ma	3M/6.5M/4M/2.5M/1M	150	NPICTA	171.00

M=1000

MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	175	100	NPILOK	$125.00
10	5	100	NPILIK	125.00
50	7	100	NPILAP	125.00
100	6	100	NPILOO	125.00
500	1.5	100	NPILIM	125.00

Any single range milliammeter from 1 milliampere, price $125.00.

1.5/3/15	150	NPILLY	141.00
3/15/30	150	NPILAB	141.00
5/20/100	100	NPILTY	141.00
7.5/30/75	150	NPILEC	141.00
10/100/1000	100	NPILAZ	141.00
15/150/1500	150	NPILTH	141.00
30/75/150	150	NPILRE	141.00
75/150/300	150	NPILUJ	141.00
100/200/500	100	NPILYM	141.00
300/750/1500	150	NPILNA	141.00
1.5/3/7.5/15/30	150	NPILST	157.00
1.5/7.5/30/150/750	150	NPILBY	157.00
1/5/10/20/50	100	NPILVO	157.00
3/15/75/300/1500	150	NPILCA	157.00
5/20/100/500/1000	100	NPILJI	157.00
75/150/300/750/1500	150	NPILDJ	157.00
100/200/500/1000/2000	100	NPILGS	157.00

AMMETERS

Range	Scale Div.	Code	Price
1	100	NPAMOL	$129.00
10	100	NPAMID	129.00
30	100	NPAMYI	133.00

Any single range ammeter from 1 to 10 amperes, price $129.00; up to 30 amperes, price $133.00. Shunts are self-contained.

.5/1/2	100	NPAMAZ	$143.00
1/5/10	100	NPAMRY	143.00
1.5/3/7.5	150	NPAMEP	143.00
2/10/20	100	NPAMIF	143.00
3/15/30	150	NPAMOJ	143.00
.75/1.5/3/7.5/15	150	NPAMUN	173.00
1/2/5/10/20	100	NPAMBO	173.00

MILLIVOLTMETERS

Range	Scale Div.	Code	Approx. Ω/mv	Price
50	100	NPMILO	1	$131.00
100	100	NPMITA	1	131.00
50/100	100	NPMILU	1	146.00

Supplied and calibrated with a pair of 5', .026 ohm leads. Normally furnished with a 100 division scale labeled "Millivolts." A 150 division scale and/or legend "Amperes" can be substituted at no extra charge. A dual scale can be drawn at an additional cost of $15.00. Scale plate can have a maximum of 4 rows of numerals. Each set of divisions normally furnished with a single row of printed numerals. Additional rows are $5.00 each.

VOLTMETERS

Additional volt ranges available as listed for the Model N on page 208. When specifying for panel mounting, identify as the Model NP and add the suffix "-P" to the code word designating the ranges of the Model N desired. Price is the same.

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5/3/7.5/30/75	150	NPVORT	$162.00	$172.00
5/10/50/100/500	100	NPVAME	162.00	172.00
30/75/150/300/750	150	NPVOLD	178.00	188.00
75/150/300/750/1500	150	NPVOLI	183.00	193.00

UNIVERSITY MODEL
COMPACT HIGH SENSITIVITY PORTABLES

MICROAMMETERS, MILLIAMMETERS,
AMMETERS, MILLIVOLTMETERS
& VOLTMETERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale; 1% accuracy on ranges below 5μa
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1-3 seconds
DAMPING	Induced emf
PIVOTS	Polished steel
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Multirange instruments switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 5 5/16" x 5 1/8" x 3 1/8" deep; carrying handle
APPROX. WEIGHT	4 1/2 lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The University Model conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. If "Diamond Pivots" are desired, add $30.00 to list prices.
2. Instruments with special scales and/or ranges available. Multirange instruments can have 5 switch controlled ranges (6 ranges if "Short" or "Off" position can be excluded) to 2 amperes and 1000 volts. 500 volts is maximum allowable voltage between switch positions. When specifying current instruments with special ranges, indicate whether high or low resistance design is desired. In the case of voltmeters, indicate ohms per volt necessary. Correspondence is required on all special instruments.
3. "Zero Center" instruments can be supplied at no extra charge. Accuracy is defined as the percentage of the sum of the left and right full scale values. (Example: A zero center instrument with a range of 10 ma-0-10 ma has the same accuracy as one with a range of 0-20 ma.)
4. Instruments can be furnished with specially designed automatic or manually operated electrical overload protection. Correspondence required.

GENERAL DESCRIPTION

The University Model comprises a complete line of precision indicating instruments whose construction and performance specifications belie their low purchase price. Despite its small size this model employs the same full size magnet and moving coil found in reference standard instruments and therefore has many distinct advantages when compared to designs of lower manufacturing cost (such as the center core magnet). It has a higher torque to weight ratio and greater sensitivity, and achieves these features while still maintaining a wide magnetic air gap between the coil, the core and the polepieces. This is an important design characteristic since it allows for stronger restoring springs with a faster response time (for an equivalent sensitivity), is less susceptible to linearity changes from long term stress relief, and is not as apt to "stick" from foreign matter caught in the air gap. Its magnetic shielding is well within ASA specifications.

Low and High Resistance current instruments are offered. Low Resistance designs are recommended for use in circuits that can tolerate only a minimum amount of loading. High Resistance instruments are in general more rugged, faster responding and lower priced. Voltmeters are offered in more than one sensitivity and the desired ohms per volt must be specified when ordering.

UNIVERSITY MODEL

Matching University Model AC/DC instruments are available in dynamometer (see Section 4), thermocouple (see Section 7) and electrostatic designs (see Section 6).

PANEL MOUNTING

A complete line of panel and switchboard instruments with the same case dimensions as the University Model is offered in the Model UPP described on pages 214-215. If specified when ordering, the University Model, at no extra charge, can be supplied with mounting hardware for *horizontal panel mounting only.*

MILLIVOLTMETERS

Range	Approx. Ω/mv	Scale Div.	Code	Price
2	5	100	UNMVAB	$118.00
5	5	100	UNMVIT	115.00
10	5	100	UNMVBI	113.00
50	5	100	UNMVLO	113.00
100	5	100	UNMVNA	113.00
50/100	5	100	UNMVUR	130.00
*2/5/10/20	5	100	UNMVSY	148.00
*2/5/20/50	5	100	UNMVSO	148.00
*2/10/50/100	5	100	UNMVTA	148.00
10/20/50/100	5	100	UNMVVE	143.00
10/50/100/200	5	100	UNMVYU	143.00

*2 mv range only on binding posts.

Instruments with ranges below 50 mv are supplied with 5', .026 ohm leads. If specified, they can be calibrated at their terminals at no extra charge. They are normally calibrated and printed in millivolts, but at no extra charge they can be furnished calibrated with external shunts and/or with 100 or 75 division scales with the legend "Amperes". If both 75 and 100 divisions (or any other combination) are desired add $15.00. The maximum number of divisions for any scale is 100. Scales are normally printed with a single set of numerals for each set of divisions. Extra rows of numerals can be printed for an additional charge of $5.00 each. A maximum of 4 rows total can be printed on an instrument scale. If it is desired to use current shunts in combination with a millivoltmeter, scales are suggested for shunt values (and multiples of 10, 100, etc.) as follows: 1) 1, 2, and 5; 100 divisions; 2) 1.5 and 7.5; 75 divisions; 3) 3 and 6; 60 divisions; 4) 2.5; 50 divisions.

UNIVERSITY MODEL
COMPACT HIGH SENSITIVITY PORTABLES

VOLTMETERS

Single range instruments available as follows: Any range from .5 v to 300 v price $98.00; over 300 v to 500 v price $100.00; over 500 v to 750 v, price $104.00; over 750 v to 1000 v, price $108.00. Prices are quoted for a sensitivity of 1000 Ω/v. All instruments are available with a sensitivity of 5000 Ω/v at an additional charge of $10.00.

Voltmeter Ranges	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5/7.5/15	75	UNVOOL	$128.00	$138.00
1.5/15/150	75	UNVOIP	128.00	138.00
3/15/75	60/75	UNVOAK	128.00	138.00
7.5/30/150	75/60	UNVOUT	128.00	138.00
15/75/150	75	UNVOSY	128.00	138.00
15/150/300	75/60	UNVORY	137.00	147.00
30/75/150	60/75	UNVOIT	128.00	138.00
75/150/300	75/60	UNVOVI	137.00	147.00
75/300/750	75/60	UNVOWO	145.00	155.00
150/300/750	75/60	UNVOXY	145.00	155.00
1.5/3/7.5/15/30	75/60	UNVOYO	153.00	163.00
3/15/75/150/300	60/75	UNVOZI	160.00	170.00
5/20/50/200/500	100	UNVOLL	163.00	173.00
15/30/75/150/300/750	75/60	UNVOSS	175.00	185.00

MICROAMMETERS

High Resistance Design Range	Approx. Resist. Ω	Scale Div.	Code	Price	Low Resistance Design Approx. Resist. Ω	Code	Price
*2	12000	100	UXNICIR	$140.00	——	——	——
*3	12000	60	UXNICCO	130.00	——	——	——
5	12000	100	UXNICAB	122.00	6400	UNICAB	$130.00
10	12000	100	UXNICED	122.00	5500	UNICED	127.00
15	7000	75	UXNICIC	120.00	3750	UNICIC	127.00
20	6400	100	UXNICOF	118.00	850	UNICOF	127.00
30	3000	60	UXNICAJ	112.00	100	UNICAJ	121.00
50	1200	100	UXNICEK	112.00	100	UNICEK	121.00
100	1200	100	UXNICIL	107.00	40	UNICIL	121.00
200	440	100	UXNICOM	107.00	10	UNICOM	121.00
300	300	60	UXNICUM	107.00	10	UNICUM	121.00
500	100	100	UXNICAP	107.00	10	UNICAP	121.00
5/20/100	6840/56600/14250	100	UXNICTO	147.00	——	——	——
10/50/100	11550/48500/27000	100	UXNICBA	142.00	5930/13000/7300	UNICBA	157.00
10/100/1000	11550/27000/2970	100	UXNICDI	142.00	5930/7260/787	UNICDI	157.00
15/30/150	11500/78000/27000	75/60	UXNICKO	142.00	5920/21500/7250	UNICKO	157.00
20/100/200	2875/11300/6325	100	UXNICIK	137.00	1042/3240/1810	UNICIK	151.00
20/200/2000	2875/6325/692	100	UXNICOJ	137.00	1042/1810/198	UNICOJ	151.00
30/150/750	2560/8100/1920	60/75	UXNICKA	135.00	794/1950/462	UNICKA	149.00
30/300/3000	2560/4525/495	60	UXNICLO	135.00	794/1090/118	UNICLO	149.00
100/1000/10000	700/500/55	100	UXNICMU	129.00	94/136/15	UNICMU	143.00
150/1500/15000	272/272/30	75	UXNICPY	129.00	46/54/6	UNICPY	143.00
200/2000/20000	143/46/5	100	UXNICRA	129.00	18/27/3	UNICRA	143.00
5/50/500/5000	6942/27050/2971/300	100	UXNICNO	160.00	——	——	——
10/100/1000/10000	11550/27000/2970/300	100	UXNICEE	155.00	5920/7260/787/79	UNICEE	170.00
20/200/2000/20000	2875/6325/692/69	100	UXNICOO	149.00	1042/1810/198/20	UNICOO	164.00
30/300/3000/30000	2560/4525/495/49	60	UXNICOY	149.00	794/1090/118/12	UNICOY	164.00
50/500/5000/50000	1145/2260/247/24	100	UXNICIO	141.00	189/315/35/3.4	UNICIO	156.00
10/30/100/300/1000	11550/68000/27000/9700/2970	100/60	UXNICII	162.00	5920/18400/6900/2750/792	UNICII	177.00
10/50/100/500/1000	11550/48500/27000/5880/2970	100	UXNICAA	162.00	5920/13000/7300/1570/792	UNICAA	177.00
30/150/300/1500/3000	2560/7600/4525/998/495	60/75	UXNICOU	152.00	794/1950/1090/235/118	UNICOU	168.00
100/500/1000/5000/10000	745/1160/547/117/59	100	UXNICUK	145.00	94/243/136/29/15	UNICUK	160.00

*Not magnetically shielded.

MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price	Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	50.0	100	UNILEC	$98.00	500	.2	100	UNILOX	$98.00
1.5	50.0	75	UNILID	98.00	1000	.1	100	UNILUY	98.00
3	10.0	60	UNILOE	98.00	.15/1.5/15	470/230/25	75	UNILMA	129.00
5	3.0	100	UNILOG	98.00	.5/2/5	150/150/95	100	UNILMD	123.00
10	2.5	100	UNILEJ	98.00	1.5/15/150	85/45/5	75	UNILME	123.00
15	1.6	75	UNILIK	98.00	3/7.5/15	16/30/15	60/75	UNILMI	123.00
20	5.0	100	UNILOL	98.00	7.5/15/30	5/14/10	75/60	UNILMY	123.00
30	2.0	60	UNILAN	98.00	15/75/150	3.5/3/2	75	UNILMU	123.00
50	1.7	100	UNILEO	98.00	30/75/300	3/3/1	60/75	UNILMF	123.00
75	1.2	75	UNILIP	98.00	50/200/500	.9/.4/.2	100	UNILMG	123.00
100	.8	100	UNILOR	98.00	75/150/300	1.1/.7/.3	75/60	UNILML	123.00
150	.7	75	UNILUS	98.00	150/300/750	.5/.3/.1	75/60	UNILMM	123.00
200	.5	100	UNILAT	98.00	200/500/1000	.5/.2/.1	100	UNILMZ	123.00
300	.3	60	UNILIW	98.00					

Range	High Resistance Design Approx. Resist. Ω	Scale Div.	Code	Price	Low Resistance Design Approx. Resist. Ω	Code	Price
.01/.1/1/10/100	11500/27000/2970/300/30	100	UXNILLO	$163.00	5930/7260/787/79/8	UNILLO	$178.00
*.01/.05/.1/.5/1/5/10/50	11550/68000/27000/6000/3000/599/299/100	100	UXNILSU	185.00	5930/18400/6900/2590/792/265/80/26	UNILSU	200.00
.02/.2/2/20/200	2875/6325/692/69/7	100	UXNILBA	157.00	1042/1810/198/20/2	UNILBA	172.00
.03/.3/3/30/300	2560/4525/495/49/5	60	UXNILDI	155.00	794/1090/118/12/1.2	UNILDI	170.00
.05/.5/5/50/500	1145/2260/247/24/2.4	100	UXNILJO	153.00	189/315/35/3.4/.35	UNILJO	168.00
.1/1/10/100/1000	745/547/59/6/.6	100	UXNILKI	153.00	47/73/8/.8/.08	UNILKI	168.00
†.1/.5/1/5/10/50/100	745/1100/547/110/59/12/6	100	UXNILFY	175.00	47/140/73/16/8/1.6/.8	UNILFY	190.00
.15/1.5/15/150/1500	268/228/25/2.4/.25	75	UXNILPY	153.00	49/55/6/.6/.06	UNILPY	168.00
.2/2/20/200	183/137/14.8/1.5	100	UXNILRO	145.00	23 32 3.5 .35	UNILRO	160.00
.5/5/50/500	100/91/9.9/1	100	UXNILEE	145.00	9.2/9.9/.9/.1	UNILEE	160.00

*10 and 50 ma ranges on binding posts; no "short" position.

†100 ma range on binding post; no "short" position.

AMMETERS: Any single range to 10 amps, price $98.00.

MODEL DCHI
HIGH RESISTANCE KILOVOLTMETERS

SPECIFICATIONS
DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% and 1% of full scale according to ranges. (See below)
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Plug-in connections
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 8" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	13 lbs. net; 23 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model DCHI conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

GENERAL DESCRIPTION

The Model DCHI is a multirange DC kilovoltmeter that provides a safe and accurate means of making high voltage measurements up to 30 kv. The indicator is a University Model .5% accurate microammeter with a basic sensitivity of either 13.3 or 20 microamperes full scale. It is self-contained in a moulded bakelite case and internally bracketed to the instrument panel. (The University Model is described on pages 210-211.)

The indicator is connected to the low side, and is in series with a high voltage multiplier which is encapsulated to keep corona to a minimum. A polarity reversing switch is located on the panel. The range connection sockets are made of polyethylene to increase the effective leakage resistance path between the high and low sides. Two extra plugs are supplied for the making up of test leads.

Because of space limitations in the instrument case, continuous operation at voltages of 25 kv or higher is not recommended. At such levels a maximum duty cycle of not more than 15 minutes in an hour is advisable.

Additional kilovoltmeters are available. Electrostatic voltmeters with an insulation resistance of $1 \times 10^{15}\Omega$ can be supplied for AC/DC measurements up to 100 kv. (See catalog section on Electrostatic Voltmeters, pages 357-360.)

OPTIONAL ACCESSORIES

Operator safety is an important consideration when making high voltage measurements and therefore an insulated probe is available and recommended for use with the Model DCHI. The probe (pictured right) has a polystyrene handle with a special hand guard, and an anti-corona ring at its tip. Its flexible test lead is a shielded high voltage cable. A convenient clip attachment is provided for those instances when such a circuit connection is desirable. Specify "High Voltage Probe." **Price $50.00**

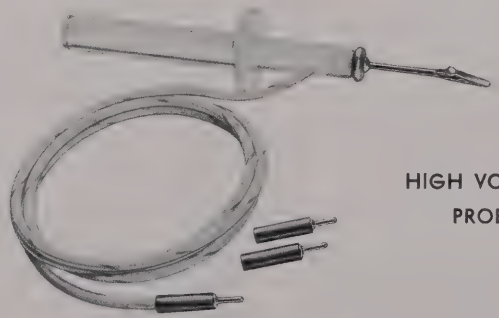
PANEL INSTRUMENTS

The Model DCHI is available in a 19" W x 7" H black bakelite rack panel with its indicating instrument mounted in a Model JW-4A case. (See pages 216-217.) Performance characteristics are the same as listed for the portable type.

Specify: Model DCHIJW-4A and code word of portable instrument having ranges desired.

Price: Add $75.00 to price of code word selected.

Note 1: The Model SEW-5A (5" scale length) or SEW-7A (7" scale length) on special order can be substituted for the Model JW-4A as the indicating instrument. (This is the Model S in an edgewise panel case as described on pages 204-205.) The Type EW-7A case can accommodate up to 150 scale divisions. Order as above except specify Model DCHIEW-5A or DCHIEW-7A and add $130.00 to price of code word selected.



HIGH VOLTAGE PROBE

KILOVOLTMETERS

Range	Accuracy	Sensitivity	Scale Div.	Code	Price
1.5/3/7.5/15	1%	50,000 Ω/v	75/60	VOLTHO	$250.00
3/7.5/15/30	1%	50,000 Ω/v	60/75	VOLTHI	260.00
2/5/10/20	.5%	75,000 Ω/v	100	VOLTHU	310.00

HIGH SENSITIVITY CALIBRATED GALVANOMETERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale; 1% accuracy for ranges below 5 μa
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 3.25"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted, except polished high carbon steel for high resistance microammeters with a base range of 5 μa or higher
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic
RANGE CHANGING	Multirange instruments switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded bakelite; 6 1/16" x 4 5/8" x 2 7/16" h.
APPROX. WEIGHT	3 1/2 lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model J conforms to ASA Specifications C-39.1.

MODEL J

OPTIONAL SPECIFICATIONS

1. Placement of binding posts must be specified when ordering. See diagram in Figure I shown below. Specify binding post location A, B, or C. Locations A or B are for portable use.
2. For use as a galvanometer, any single range Model J is available with a "Zero Center" scale at no additional charge. Specifications remain the same. Accuracy is defined as the percentage of the sum of the left and right full scale values. (Example: a 10-0-10 μa instrument has the same specification as a 0-20 μa instrument.)
3. Diamond Pivots where not normally supplied, add $30.00.
4. "Press-to-read" switch with normal open circuit, add $15.00.
5. Special scales and/or ranges available. Correspondence required.

GENERAL DESCRIPTION

The Model J instrument is recommended for use where exceptionally high sensitivity as well as relatively high accuracy is required in a space saving instrument. It has wide application as a horizontally mounted, calibrated galvanometer with better than .5% linearity. Despite its small size, the Model J uses the same full-size Alnico magnet and moving coil assembly employed in the models S and C.

PANEL MOUNTING

The Model J can be supplied for flush mounting in a horizontal panel at no extra charge. Binding posts can be furnished as per locations "B" or "C" noted below.

MICROAMMETERS

High Resistance Design

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	7000	50	JICII	$175.00
1.5	7000	75	JICEE	145.00
2	5500	40	JICIP	135.00
3	5500	60	JICLA	135.00
5	5500	50	JICMO	117.00
10	1200	50	JICNU	112.00
15	900	75	JICOO	107.00
20	440	40	JICRI	107.00

Low Resistance Design

Range	Approx. Resist. Ω	Scale Div.	Code	Price
5	2600	50	JICAA	$138.00
10	900	50	JICBC	132.00
15	150	75	JICPY	130.00
20	100	40	JICEF	125.00
25	50	50	JICGM	125.00
30	50	60	JICVU	110.00
50	15	50	JICHI	110.00
100	5	50	JICCI	110.00

High Resistance Design

Range	Approx. Resist. Ω	Scale Div.	Code	Price
2.5/10/50	5500/60000/13500	50	JXICSOL	$161.00
5/25/100	5600/37000/11750	50	JXICDOG	154.00
5/50/500	5600/22000/2350	50	JXICBIP	154.00
10/100/1000	4480/9000/998	50	JXICERB	139.00

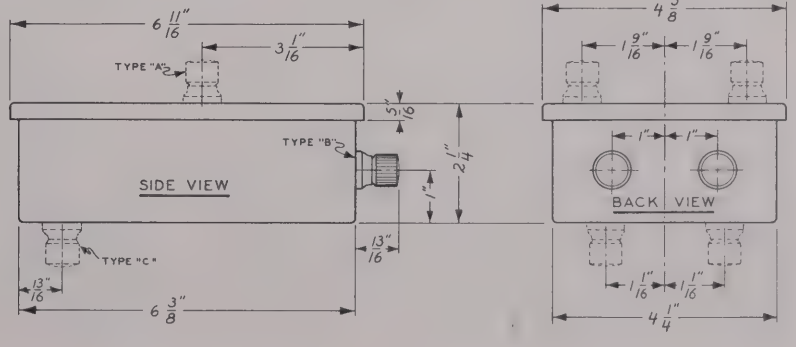
Low Resistance Design

Approx. Resist. Ω	Code	Price
4600/16000/4800	JICDOG	$165.00
4600/9900/1000	JICBIP	165.00
2840/4990/498	JICERB	150.00

MILLIVOLTMETERS

Range	Approx. Ω/mv	Scale Div.	Code	Price
1	5	50	JMVKAT	$132.00
2	5	40	JMVKEK	127.00
5	5	50	JMVKOS	125.00

Supplied and calibrated with 5', .026 ohm leads.



Possible locations of Model J binding posts. → Location must be specified at time of ordering.

MODEL UPP
COMPACT RECTANGULAR PANEL INSTRUMENTS

SPECIFICATIONS
DC RECTANGULAR PANEL INSTRUMENT

ACCURACY	.5% of full scale; 1% accuracy on ranges below 200 μa
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1 second
DAMPING	Induced emf
PIVOTS	Polished high carbon steel
JEWELS	Sapphire
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Multirange instruments are switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 5 5/16" x 5 3/8" x 3 3/16" deep (See page 215 for mounting dimensions.)
APPROX. WEIGHT	4 1/2 lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model UPP conforms to the following specifications: ASA C-39.1; and on request MIL-M-16034B.

OPTIONAL SPECIFICATIONS

1. Lance type pointers and/or heavier scale markings can be furnished at no extra charge if specified.

2. Instruments with special scales and/or ranges available. Multirange instruments can have 5 switch controlled ranges (6 ranges if "Short" or "Off" position can be omitted) to 2 amperes and 1000 volts. 500 volts is maximum allowable voltage between switch positions. When specifying voltmeters state Ω/v desired. 1000 Ω/v is standard. 5000 Ω/v is available for ranges of 1.5 volts and above. Correspondence is required for all special instruments.

3. "Zero Center" instruments can be supplied at no extra charge. Accuracy is defined as the percentage of the sum of the left and right full scale values.

4. Instruments can be furnished with specially designed automatic or manual electrical overload protection. Correspondence required.

5. While multirange instruments are normally supplied with a range selector switch, they are also available at no extra charge with terminals in the rear.

GENERAL DESCRIPTION

The Model UPP is a rectangular panel instrument for flush or projection mounting as per dimensions listed on page 215. Flush mounting is supplied unless otherwise specified. It is similar in construction to the University Model described on pages 210-211, and has all the characteristics of a precision, compact portable. Instruments with a lowest range of 1.5 v. or 200 μa or higher, have extremely strong restoring springs and consequently experience *no difficulty with zero return, repeatability or balance.*

Magnetic shielding is well within ASA specifications. However, as an additional service at no extra charge, if a series of instruments are to be mounted in close proximity to each other, they can be calibrated duplicating their exact operating positions.

Note: The Model UPP is not available with diamond pivots and/or shock mounted jewels, unless it will be used in a horizontal panel. The additional charge in such cases is $30.00.

MICROAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
30	12000	60	UPPICOX	$110.00
50	12000	100	UPPICUS	110.00
100	6400	100	UPPICEM	105.00
200	6000	100	UPPICOP	105.00
300	3000	60	UPPICUB	105.00
500	800	100	UPPICAP	105.00
750	250	75	UPPICET	105.00
50/100/250	10950/34000/20400	50	UPPICED	124.00
50/250/500	10950/20400/10200	50	UPPICUR	124.00
50/250/1000	10950/20400/5950	50	UPPICOT	124.00
100/500/1000	5730/9000/5000	100	UPPICOK	119.00
50/250/500/1000/2500	10200/19600/10900/5640/2360	50	UPPICOW	142.00
75/150/300/750/1500	5820/17700/12600/5900/3100	75/60	UPPICUT	140.00
75/300/750/1500/3000	5820/12600/5900/3100/1585	75/60	UPPICYL	140.00
100/250/500/1000/2500	5730/14100/9000/4560/2160	50	UPPICAR	137.00
150/300/750/1500/3000	5780/11900/11900/5460/2860	75/60	UPPICEX	137.00
100/500/1000/2500/5000	5730/9000/4560/2160/1080	50	UPPICIK	137.00

NOTE: All microammeters with a basic range of less than 200 μa have an accuracy of 1%.

MILLIAMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1.0	175	100	UPPILEC	$ 98.00
2	38	100	UPPILID	98.00
5	18	100	UPPILOE	98.00
10	4	100	UPPILUF	98.00
15	3	75	UPPILAG	98.00
20	2	100	UPPILEJ	98.00
30	1.2	60	UPPILOL	98.00
50	7	100	UPPILUM	98.00
100	6	100	UPPILAP	98.00
150	3	75	UPPILER	98.00
200	2	100	UPPILIS	98.00
300	1.4	60	UPPILUV	98.00
500	1.2	100	UPPILAW	98.00
750	1	75	UPPILEX	98.00
1/5/10	140/260/145	100	UPPMILBS	123.00
1.5/3/15	43/135/45	75/60	UPPMILCT	123.00
3/7.5/15	33/79/50	60/75	UPPMILGS	123.00
3/15/30	33/49/27	60/75	UPPMILHT	123.00
7.5/15/30	22/30/22	75/60	UPPMILJE	123.00
7.5/30/75	22/10/6	75/60	UPPMILKO	123.00
10/50/100	15/15/9.2	100	UPPMILLE	123.00
15/30/75	8.3/14/8.3	75/60	UPPMILND	123.00
15/75/150	8.3/8.3/4.6	75	UPPMILOS	123.00
30/75/150	4.2/6.6/4.2	60/75	UPPMILRO	123.00
30/150/300	4.2/4.2/2.4	60/75	UPPMILSI	123.00
50/200/500	3.8/3/1.4	100	UPPMILTO	123.00
75/150/300	3.3/3.3/2.1	75/60	UPPMILUZ	123.00
100/200/500	3/2/1	100	UPPMILVV	123.00
200/500/1000	2/1/.5	100	UPPMILWE	123.00
1.5/3/15/75/150	43/135/45/10/5	75/60	UPPMILOK	138.00
3/7.5/30/150/300	33/79/27.5/5.9/2.9	60/75	UPPMILET	138.00
5/20/100/200/500	14/15/4/2/.8	100	UPPMILAR	138.00
15/75/150/300/750	8.3/8.3/4.6/2.5/1	75/60	UPPMILKY	138.00
30/75/150/300/750	4.2/6.6/4.2/2.4/1	60/75	UPPMILNI	138.00
30/75/300/750/1500	4.2/6.6/2.4/1/.5	60/75	UPPMILUT	138.00

RECTANGULAR PANEL INSTRUMENTS

MODEL UPP

AMMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1	.15	100	UPPAMAB	$ 98.00
2	.075	100	UPPAMEK	98.00
3	.05	60	UPPAMID	98.00
5	.03	100	UPPAMEF	98.00
7.5	.02	75	UPPAMOF	98.00
10	.015	100	UPPAMER	100.00
15	.005	75	UPPAMIG	102.00
20	.004	100	UPPAMUL	105.00
30	.002	60	UPPAMGI	115.00
50	.0015	100	UPPAMHU	125.00

MILLIVOLTMETERS

Range	Approx. Resist. Ω	Scale Div.	Code	Price
50	12	100	UPPMVKA	$110.00
100	24	100	UPPMVSI	110.00
50/100	12/24	100	UPPMVTU	135.00

All millivoltmeters are calibrated and supplied with a pair of 5′, .026 ohm leads. If specified, they can be calibrated at their terminals. They are normally calibrated and printed in millivolts, but at no extra charge they can be furnished calibrated with external shunts and/or the scale legend "Amperes." If both 75 and 100 divisions (or any other dual combination) are desired, add $15.00. The maximum number of divisions for any scale is 100. Scales are normally printed with a single set of numerals for each set of divisions. Extra rows of numerals can be printed for an additional charge of $5.00 each. A maximum of 4 rows total can be printed on an instrument scale. If it is desired to use current shunts in combination with a millivoltmeter, scales are suggested for shunt values (and multiples of 10, 100 etc.) as follows: 1) 1, 2, and 5; 100 divs.; 2) 1.5 and 7.5; 75 divs.; 3) 3 and 6; 60 divs.; 4) 2.5; 50 divs.

VOLTMETERS

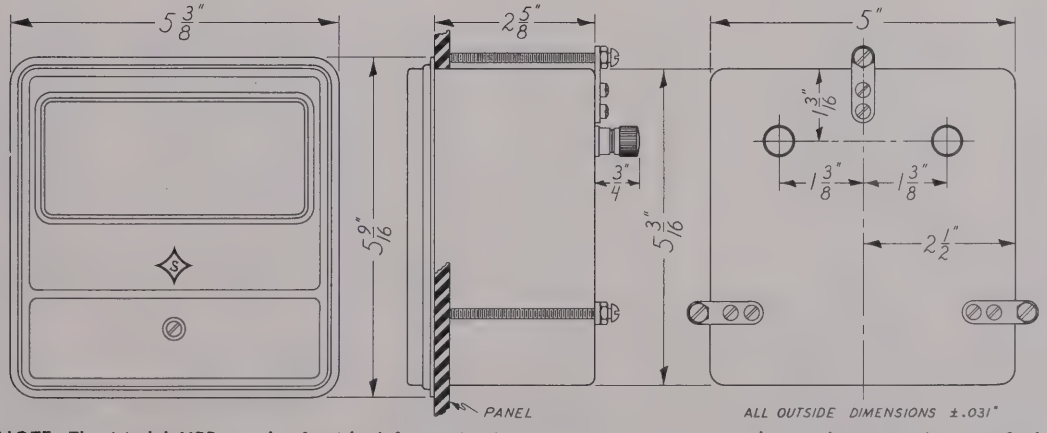
Any single range voltmeter available as follows: 1 v to 300 v price, $98.00; over 300 v to 500 v, price $100.00; over 500 v to 750 v, price, $104.00; over 750 v to 1000 v, price $108.00. Prices are listed for sensitivities of 1000 ohms per volt. 5000 Ω/v sensitivity is available at an additional charge of $10.00 starting with a lowest range of 1.5 v.

VOLTMETERS

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5/7.5/15	75	UPPOLSI	$128.00	——
3/15/30	60/75	UPPOLDI	128.00	——
5/50/100	100	UPPOLZY	128.00	——
7.5/30/75	75/60	UPPOLFU	128.00	$138.00
10/50/200	100	UPPOLGY	130.00	140.00
10/100/500	100	UPPOLHA	140.00	150.00
15/30/75	75/60	UPPOLIZ	128.00	138.00
15/75/150	75	UPPOLJO	128.00	138.00
30/75/150	60/75	UPPOLMA	128.00	138.00
30/150/300	60/75	UPPOLNI	137.00	147.00
75/150/300	75/60	UPPOLOT	137.00	147.00
150/300/750	75/60	UPPOLPY	145.00	155.00
*200/500/1000	100	UPPOLRA	150.00	160.00
3/7.5/30/150/300	60/75	UPPOLTU	160.00	——
10/20/100/200/500	100	UPPOLII	163.00	173.00
15/75/150/300/750	75/60	UPPOLVO	168.00	178.00
30/75/150/300/750	60/75	UPPOLWA	168.00	178.00
*50/100/200/500/1000	100	UPPOLYN	173.00	183.00

*Supplied with part of its multiplier in a small cage attached to the rear of the case.

MODEL UPP MOUNTING DIMENSIONS



NOTE: The Model UPP can be furnished for projection mounting at no extra charge, but must be specified.

MODEL JW-4A COMPACT EDGEWISE PANEL INSTRUMENTS

SPECIFICATIONS

DC EDGEWISE PANEL INSTRUMENT

ACCURACY	.5% of full scale; 1% accuracy on ranges below 5 μa
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1-3 seconds
DAMPING	Induced emf
PIVOTS	Polished high carbon steel
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts or terminal strips
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External front zero shifter
CASE	Cast aluminum; black wrinkle finish; see dimensions on page 220
APPROX. WEIGHT	4½ lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. Conforms to ASA C-39.1 specifications; and on request MIL-M-16034B.

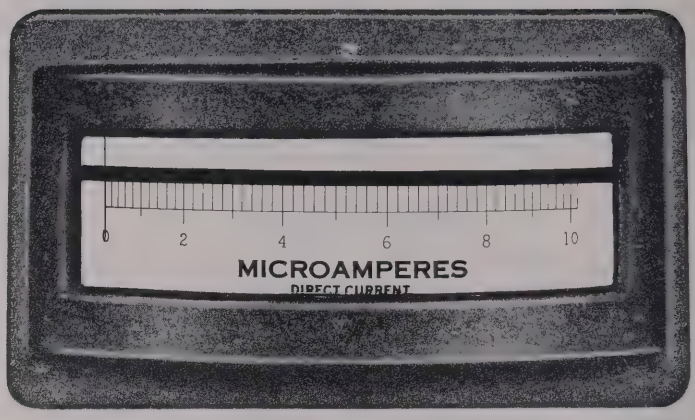
OPTIONAL SPECIFICATIONS

1. If Diamond Pivots are desired, add $30.00.
2. Instruments with special ranges and/or scales and added overload protection available. Correspondence required.
3. "Zero Center" instruments can be supplied at no extra charge. Accuracy is rated in percentage of the sum of the right and left full scale values.

GENERAL DESCRIPTION

The Model JW-4A is an edgewise instrument for flush mounting in a vertical panel. It features high sensitivity and .5% accuracy in a compact case that takes up only a minimum of panel space. Shielding is well within ASA specifications. It is in all respects equivalent in performance to a precision portable.

MODEL JW-4A



MILLIAMMETERS

Single range milliammeters from 1 ma to 1500 ma, price $110.00.
Any multirange milliammeter as listed below, price $130.00.

Range	Approx. Resist. Ω	Scale Div.	Code
.5/2.5/5	100/150/95	50	JAWLIO
1.5/15/150	85/45/5	75	JAWLIP
3/7.5/15	16/30/15	60/75	JAWLIR
7.5/15/30	5/14/10	75/60	JAWLIV
15/75/150	3.5/3/2	75	JAWLIS
30/75/300	3/3/1	60/75	JAWLIT
50/250/500	.9/.4/.2	50	JAWLIW
75/150/300	1.1/.7/.3	75/60	JAWLIX
150/300/750	.5/.3/.1	75/60	JAWLAA
200/500/1000	.4/.2/.1	40/50	JAWLUU

MICROAMMETERS

	High Resistance Design				Low Resistance Design		
Range	Approx. Resist. Ω	Scale Div.	Code	Price	Approx. Resist. Ω	Code	Price
*2	7100	40	JAWMIC-X	$145.00	——	——	——
*3	7100	60	JAWMIB-X	135.00	——	——	——
10	7100	50	JAWMIT-X	115.00	5800	JAWMIT	$125.00

Note: Any single range microammeter from 15 μa, price $110.00 for high resistance design; $120.00 for low resistance design.

*2.5/10	7100/375,000	50	JAWMUE-X	155.00	——	——	——
*3/6	5800/101,000	60	JAWMOO-X	150.00	——	——	——
5/10	7100/78000	50	JAWMAA-X	140.00	5800/75000	JAWMAA	150.00
10/20	6900/74000	50/40	JAWMII-X	130.00	2500/26500	JAWMII	140.00
5/20/100	7100/57000/15000	50/40	JAWMIQ-X	150.00	5800/56600/14250	JAWMIQ	160.00
10/50/100	6900/48500/27000	50	JAWMIR-X	140.00	2500/13000/7300	JAWMIR	150.00
10/100/1000	6900/27000/2970	50	JAWMIU-X	140.00	2500/7260/787	JAWMIU	150.00
15/30/150	6900/78000/27000	75/60	JAWMIH-X	130.00	2500/21500/5000	JAWMIH	140.00
20/100/200	2500/11300/6325	40/50	JAWMIJ-X	130.00	1042/3240/1810	JAWMIJ	140.00
20/200/2000	2500/6325/692	40	JAWMIK-X	130.00	1042/1810/198	JAWMIK	140.00
30/150/750	1200/8100/1920	60/75	JAWMIL-X	130.00	500/1950/462	JAWMIL	140.00
30/300/3000	1200/4525/495	60	JAWMIM-X	130.00	500/1090/118	JAWMIM	140.00
50/500/5000	900/2260/247	50	JAWMIV-X	130.00	189/315/35	JAWMIV	140.00
100/1000/10000	500/490/55	50	JAWMID-X	130.00	94/136/15	JAWMID	140.00
150/1500/15000	180/272/30	75	JAWMIW-X	130.00	46/54/6	JAWMIW	140.00
200/2000/20000	177/46/5	40	JAWMIA-X	130.00	18/27/3	JAWMIA	140.00

*Not magnetically shielded.

SPECIAL "ZERO CENTER" LOW RESISTANCE MICROAMMETERS

The high sensitivity microammeters listed at right are recommended for use whenever a calibrated galvanometer with negligible "zero creep" is necessary. They can be used either as null detectors or 1% measuring instruments. Diamond pivots and spring mounted jewels are included in the price.

Range	Approx. Resist. Ω	Scale Div.	Code	Price
15/0/15	150	15/0/15	JAWGAL	$131.00
25/0/25	50	25/0/25	JAWGAK	131.00
100/0/100	5	20/0/20	JAWGAM	131.00

MODEL JW-4A AND MODEL JWSP COMPACT EDGEWISE PANEL INSTRUMENTS

AMMETERS

Single range ammeters from 2 amps to 20 amps, price $115.00

VOLTMETERS

When ordering voltmeters specify ohms per volt desired.

Any single range voltmeter with a sensitivity of 1000 Ω/v as follows: 1 v to 150 v, price $113.00; above 150 v to 300 v, price $120.00; above 300 v to 1000 v, price $125.00. Available with 5000 Ω/v sensitivity at $10.00 additional.

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5/7.5/15	75	JAWVOPO	$138.00	$148.00
1.5/15/150	75	JAWVOSK	138.00	148.00
2/20/200	40	JAWVOJA	138.00	148.00
3/15/75	60/75	JAWVOOL	138.00	148.00
7.5/30/150	75/60	JAWVOXO	138.00	148.00
15/75/150	75	JAWVOBU	138.00	148.00
15/150/300	75/60	JAWVOCA	147.00	157.00
30/75/150	60/75	JAWVODI	138.00	148.00
75/150/300	75/60	JAWVOFE	147.00	157.00

MILLIVOLTMETERS

Millivoltmeters are calibrated and printed in millivolts but, at no extra charge, can be supplied calibrated with external shunts and a special scale with the legend "Amperes". Special scales can have a maximum of 75 divisions. The number of divisions should be selected for convenient reading of the shunt in amperes. A maximum of 3 scales can be drawn and printed. Additional charge is $15.00 for each *extra* scale and $5.00 for each *extra* row of numerals (3 rows max. for a single scale).

Millivoltmeters with ranges below 5 mv supplied with 5', .026 Ω leads. If specified, calibration can be made at the instrument's terminals at no extra charge.

Any single range millivoltmeter from 1.5 mv to 7.5 mv, price $128.00; from 10 mv to 500 mv, price $123.00. Sensitivity is 5 Ω/mv.

Range	Approx. Ω/mv	Scale Div.	Code	Price
1.5/6	5	75/60	JAWVOB	$145.00
2/5	5	40/50	JAWVOC	143.00
2/5/10	5	40/50	JAWVOG	153.00
2/10/20	5	40/50	JAWVOX	153.00
50/100	5	50	JAWVOR	138.00

MODEL JWSP

GENERAL DESCRIPTION

The Model JWSP is a compact edgewise panel instrument with an internal range selector switch. Specifications are the same as listed for the Model JW-4A on page 216. Dimensions are diagramed on page 220. Only multirange instruments are catalogued. Any single range or multirange Model JW-4A is available in a JWSP case at an additional cost of $15.00. Multirange instruments are switch controlled.

Special ranges and/or scales are available. Correspondence required. A maximum of 5 ranges up to 1.5 amps and 500 v (no more than 300 v between switch positions) including an "Off" or "Short" position can be supplied switch controlled.

MILLIVOLTMETERS

Millivoltmeters are supplied and calibrated with a pair of 5', .026 ohm leads. Calibration can be made at the instrument's terminals at no extra charge if specified. Specifications same as for Model JW-4A millivoltmeters listed at top of page.

Range	Approx. Ω/mv	Scale Div.	Code	Price
*2.5/5/10/25	5	50	JASPVA	$173.00
*2.5/5/25/50	5	50	JASPVE	173.00
*2.5/10/50/100	5	50	JASPVO	173.00
10/25/50/100	5	50	JASPVI	168.00
10/50/100/250	5	50	JASPVU	168.00

*2.5 mv ranges on binding posts.

VOLTMETERS

Range	Scale Div.	Code	Price 1000 Ω/v	Price 5000 Ω/v
1.5/30/150/750	60/75	JASPZI	$175.00	$185.00
5/25/50/250	50	JASPZU	167.00	177.00
15/75/150/300	60/75	JASPZE	167.00	177.00

When ordering specify Ω/v desired.

MICROAMMETERS

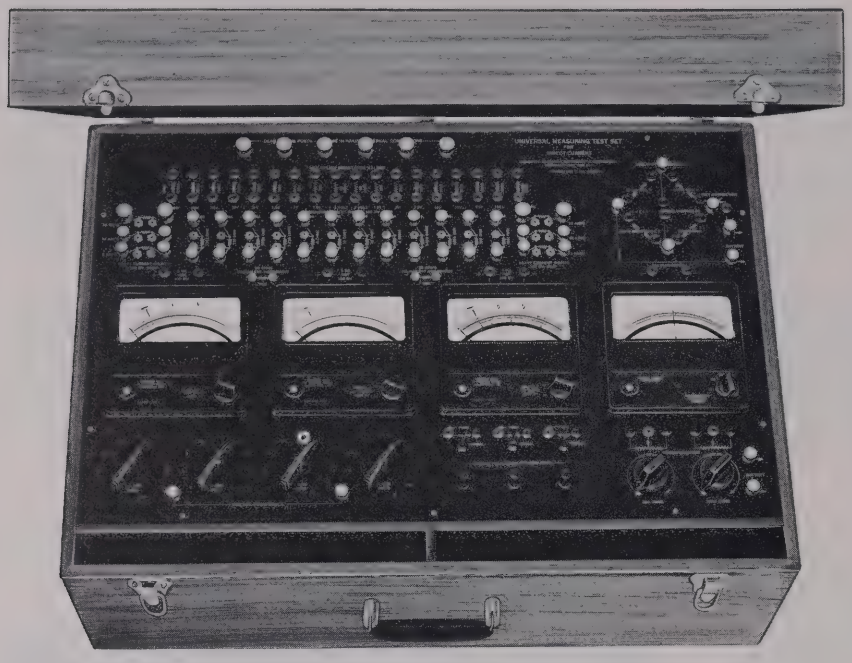
Range	High Resistance Design: Approx. Resist. Ω	Scale Div.	Code	Price	Low Resistance Design: Approx. Resist. Ω	Code	Price
5/50/500/5000	6942/27050/2971/300	50	JASPNO	$175.00	———	———	———
10/100/1000/10000	11550/27000/2970/300	50	JASPEE	165.00	5920/7260/787/79	JASPEE-S	$175.00
20/200/2000/20000	2875/6325/692/69	40	JASPOO	155.00	1042/1810/198/20	JASPOO-S	165.00
30/150/300/1500	1200/7600/4525/998	60/75	JASPOU	155.00	500/1950/1090/235	JASPOU-S	165.00
30/300/3000/30000	2560/4525/495/49	60	JASPOY	155.00	794/1090/118/12	JASPOY-S	165.00
50/100/500/1000	900/6300/2260/1100	50	JASPAA	155.00	189/875/315/170	JASPAA-S	165.00
100/500/1000/5000	500/1160/547/117	50	JASPUK	155.00	94/243/136/29	JASPUK-S	165.00

MILLIAMMETERS

Range	High Resistance Design: Approx. Resist. Ω	Scale Div.	Code	Price	Low Resistance Design: Approx. Resist. Ω	Code	Price
.05/.5/5/50	900/2260/247/24	50	JASPLY	$155.00	189/315/35/3.4	JASPLY-S	$165.00
.1/1/10/100	500/547/59/6	50	JASPLA	155.00	47/73/8/.8	JASPLA-S	165.00
.2/2/20/200	183/137/14.8/1.5	40	JASPIL	155.00	23/32/3.5/.35	JASPIL-S	165.00
.3/3/30/300	180/135/15/1.5	60	JASPLU	155.00	24/33/3.5/.35	JASPLU-S	165.00
.5/2/5/20	100/180/91/24	40/50	JASPUS	155.00	9.2/18/9.9/2.4	JASPUS-S	165.00
.5/5/50/500	100/91/9.9/1	50	JASPUZ	155.00	9.2/9.9/.9/.1	JASPUZ-S	165.00
1/10/100/1000	547/59/6/.6	50	JASPUB	155.00	73/8/.8/.08	JASPUB-S	165.00
1.5/15/150/1500	85/45/5/.5	75	JASPUF	155.00	55/6/.6/.06	JASPUF-S	165.00

MODEL UTS
DC UNIVERSAL TEST SET

MODEL UTS



The Model UTS is a direct reading portable DC test set designed to measure a wide range of currents and voltages in an unusual variety of applications. The test set basically consists of:

- Three identical .5% accurate milliammeters with a sensitivity of 5 ma, 100 mv full scale.
- One "Zero Center" .5% accurate microammeter (or galvanometer) with a basic sensitivity of 50μa, 15 mv full scale.
- One .1% accurate 4 dial decade resistance box with a range of 0-1111Ω in steps of .1Ω.
- Two sets of .1% accurate shunts and multipliers for "plug-in" connection to the indicating instruments to extend their nominal range to measure amperes, volts and kilovolts.
- Accessory component items such as 3 DPDT switches, a fine (200Ω) and coarse (2000Ω) rheostat, circuit closing keys, extra binding posts and test leads with additional plugs.

SPECIFICATIONS

1. Indicating Instruments

The electrical indicating instruments employed are the $\pm$.5% accurate University Model, specifications for which are described on pages 210-211.

The 3 milliammeters have a basic sensitivity of 5 ma full scale and an internal resistance of 20Ω. Each instrument contains a "Turn to Lock" button to insert a manual overload protection system. With the safety button in the upright position, each moving coil is shunted for up to 5000% overload protection. In operation, overloads are indicated when the instruments deflect above a red "safety" line. Depressing the buttons for normal operation does not unbalance the measuring circuits. (See Fig. 1.) Each milliammeter also contains a range factor switch marked X1 and X2. They have dual scales with 75/100 divisions printed 0-15/30/75 and 0-100.

The microammeter (or galvanometer) contains a manual "Depress to Read" circuit closing switch and a range factor switch. It has a 100 division scale printed 50-0-50 and 5 self-contained ranges (see Fig. 2) as follows:

Switch Factor	Range μa	Approx. Resist. Ω
X1	50/0/50	300
X3	150/0/150	1365
X10	500/0/500	540
X30	1500/0/1500	175
X100	5000/0/5000	60

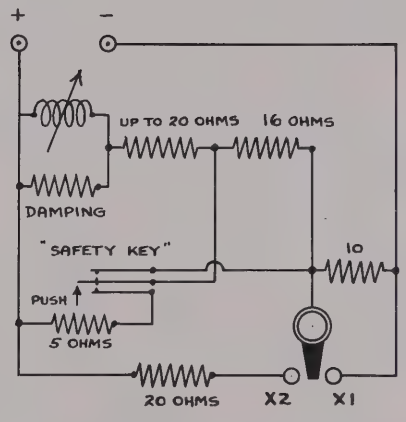


Fig. 1. Milliammeter and Overload Protection Circuit. A constant resistance of 20Ω is maintained.

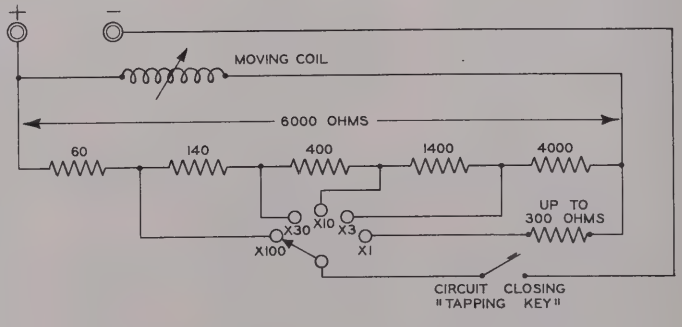


Fig. 2. Microammeter Circuit.

2. Range Extension

The range of the milliammeters can be extended by plugging into shunts or multipliers as indicated by the circuitry marked on the panel of the test set. This is simple and convenient since each resistance is identified by its value in ohms and the range it provides when used as a shunt or series connection to the indicating instrument. The ranges listed (right) are obtained by the use of a single shunt or multiplier only, and by switching range factors. Since there are 2 complete sets of shunts and multipliers, combinations of resistances in parallel and series may be used to get in-between ranges or extend ranges considerably. (Example: Connect instrument to 60,000Ω resistor. With range factor on X2, full scale deflection is 600 v. However, by connecting the other 60,000Ω resistor in series, full scale deflection becomes 1200 v.)

The decade resistance box can also be used as a shunt or multiplier. It is possible to read the indicating instruments at, or near full scale if desired by using this box as a variable resistor. Since accuracy is in terms of full scale, this feature is of importance.

Range Factor X1	Range Factor X2	Shunt Resist. Ω	Watt Rating
5 ma	10 ma	–	–
15 ma	30 ma	10	1
30 ma	60 ma	4	1
75 ma	150 ma	1.428	1
150 ma	300 ma	.6896	1
300 ma	600 ma	.339	1
750 ma	1500 ma	.1342	1
3 amps	6 amps	.033	1.2
10 amps	20 amps	.01	4
30 amps	60 amps	.00333	12

Range Factor X1	Range Factor X2	Multiplier Resist. Ω	Watt Rating
.1 v	.2 v	–	–
.3 v	.6 v	40	1
1.5 v	3 v	280	1
3 v	6 v	580	1
7.5 v	15 v	1480	1
15 v	30 v	2980	1
30 v	60 v	5980	1
75 v	150 v	15000	1.5
150 v	300 v	30000	3
300 v	600 v	60000	6

3. Decade Resistance Box

Total resistance range is 0-1111Ω in steps of .1Ω. There are 4 decades. Each has 10 steps as follows:

Decade Resist. Steps	Max. Current Rating	Accuracy
.1Ω	1 amp	±.5%
1Ω	.3 amp	±.25%
10Ω	.1 amp	±.1%
100Ω	.03 amp	±.1%

4. Case

Sturdy oak case has a removable hinged cover, compartment for storage of test leads and carrying handle. Panel is of black bakelite. Size is 25″ x 18¼″ x 7″ deep. Approximate weight is 45 lbs. net, 140 lbs. shipping.

OPTIONAL SPECIFICATIONS

1. Diamond Pivots available at an additional charge of $30.00 per indicating instrument.

APPLICATION INFORMATION

The Model UTS has exceptional versatility! Consider the following usages:

A. Direct reading millivoltmeter, voltmeter, kilovoltmeter, microammeter, milliammeter and ammeter. Each milliammeter can be any of the preceding instruments in various combinations. Since there are 2 sets of shunts and multipliers, it is possible to have 2 voltmeters and 1 ammeter, or 2 milliammeters and 1 millivoltmeter, or 1 ammeter, 1 milliammeter and 1 kilovoltmeter or any other similar combination of instruments. The microammeter can be a current measuring instrument, a high sensitivity null detector, or when connected to series resistances, a high resistance voltmeter.

B. Wheatstone Bridge. The circuit is marked on the panel and plug-in connections are installed for a Wheatstone Bridge to measure resistance.

C. Potentiometer Voltmeter. A conventional voltmeter draws current from the circuit being measured. The potentiometer voltmeter has infinite resistance at null and is particularly effective where high sensitivity is required such as is encountered in corrosion and electrolysis applications, and in the measurement of the output of thermocouples. (See Fig. 3.) The potentiometer voltmeter type of instrument is described more fully on page 507 of Section 9.

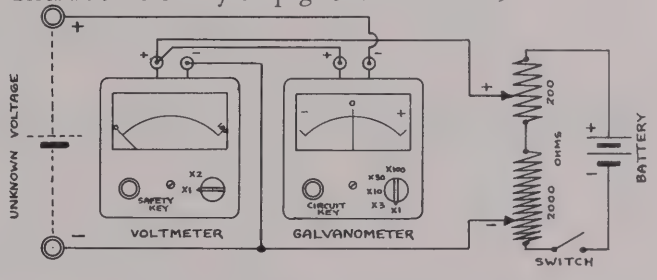


Fig. 3. Potentiometer Voltmeter Measurements

D. Zero Resistance Microammeter and Milliammeter. This instrument setup effectively introduces zero resistance into a circuit when employed for measuring current. It is particularly valuable in electrolysis and corrosion work, and in the measurement of the output of photocells. (See Fig. 4.) The zero resistance type of instrument is described more fully on page 508 in Section 9.

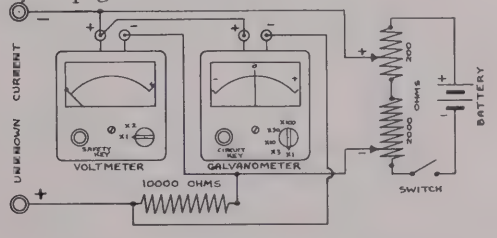


Fig. 4. Zero Resistance Current Measurements

E. DC Power Measurements. Measurements may be made from a few millivolts to over 20 kilowatts.

F. Radio Frequency Measurements. The microammeter can be used as a millivoltmeter with a range of 0-15 mv full scale to measure the output of a vacuum thermocouple.

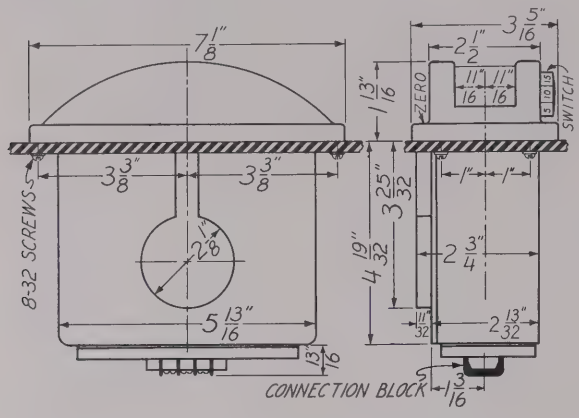
Model UTS Code UNITEST Price $995.00

MOUNTING DIMENSIONS FOR PANEL INSTRUMENTS

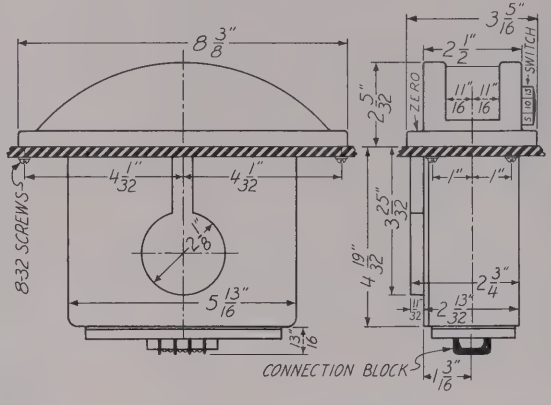
Edgewise panel cases are supplied for flush mounting in a vertical panel. Binding posts or connection lugs are furnished in the rear. Cases are of die cast aluminum with a black wrinkle finish. Switches, when supplied, are as indicated in the drawings. (See individual portable model specifications for specific information on instruments that are to be installed in EW-5A and EW-7A cases.) External zero shifters are supplied on the front of all cases.

NOTE

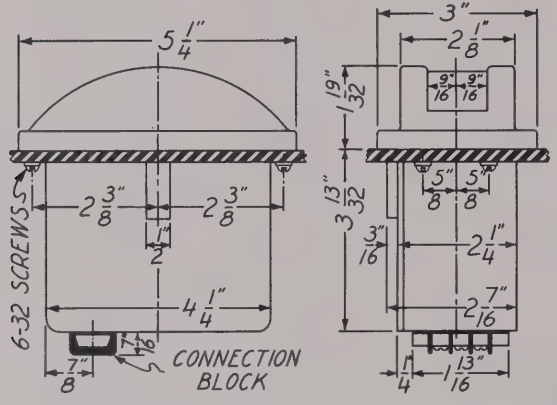
The Types EW-5A, EW-7A and JW-4A replaced the Types EW-5, EW-7 and JW-4 in May 1961. There are minor dimensional differences between the types. For purposes of exact replacement, the Types EW-5, EW-7 or JW-4 can be supplied at no additional charge, *but must be specified at time of ordering.*



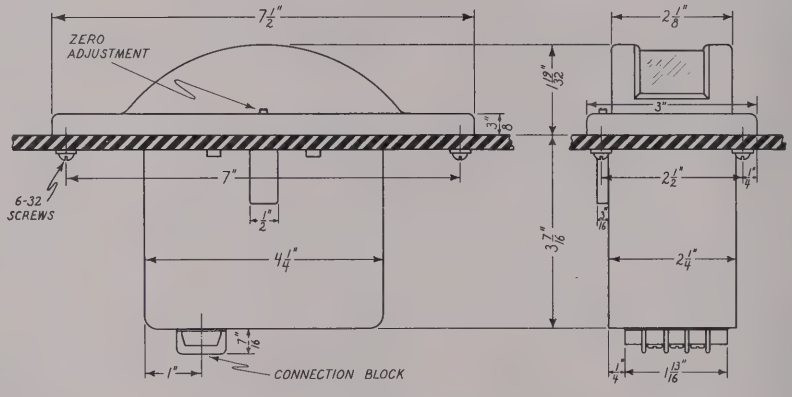
Type EW-5A Shallow Case, Scale Length 5"
for Models C, S, HS, FS, FM, FLV, FLVC



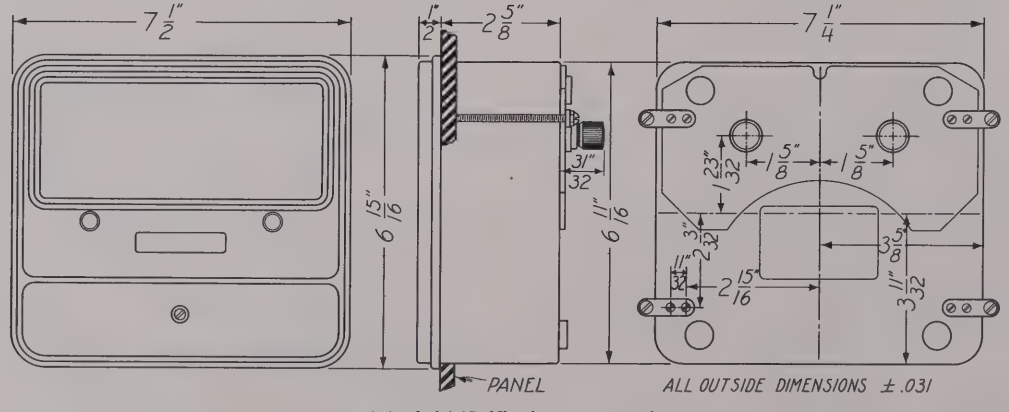
Type EW-7A Shallow Case, Scale Length 7"
for Models C, S, HS, FS, FM, FLV, FLVC



Model JW-4A, Scale Length 4"

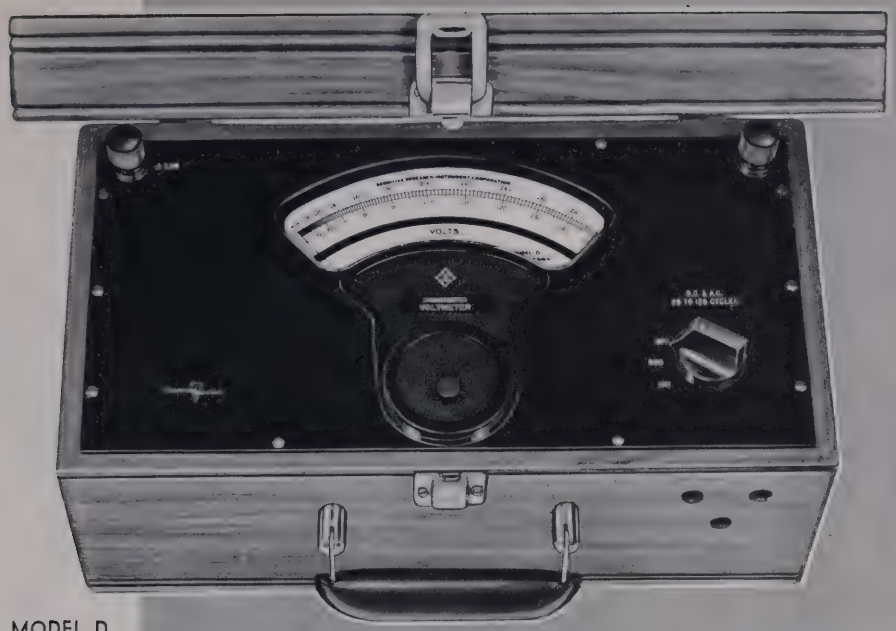


Model JWSP, Scale Length 4"



Model NP (flush mounting)

Mounting dimensions for the Model UPP are shown on page 215.



MODEL D

MODEL DEW-7A

Portable and Panel
AC/DC and AC Reference Standard

DYNAMOMETER
and
MOVING IRON
Ammeters, Milliammeters and Voltmeters

Model	Description	Page
D	.25% AC/DC Dynamometer Ammeters, Milliammeters and Voltmeters. 6.3" Scale length	252-254
University	.5% AC/DC Dynamometer Ammeters, Milliammeters and Voltmeters. 4" Scale length	255
MI	.5% AC Moving Iron Ammeters, Milliammeters and Voltmeters. 6.3" Scale length	256
NSI	.5% AC Moving Iron Ammeters, Milliammeters and Voltmeters. 6" Scale length	257

Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N. Y.

S. STERLING CO
Manufacturers' Representatives
3300 SOUTH DIXIE DR
DAYTON 39, OHIO
AX 8-7573

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

Symbol of Quality

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. — *Electrical Measuring Instruments Since 1927*

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
FREQUENCY	See individual ranges
TYPE	Electrodynamometer
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2–3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Single and double range binding posts only; three or more ranges switch controlled
MECHANICAL ZERO	External zero shifter
CASE	Formica; Size 11 case 7¾"x7¾"x6½" h.; Size 12 case 13¾" x 7½" x 6½" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 12 lbs. shipping (Size 11 case) 12 lbs. net; 16 lbs. shipping (Size 12 case)

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The Model D conforms to the following specifications: ASA C-39.1; and on request Mil-M-16034B

All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases are made of tough, durable formica and are gasketed to provide an effective dust and humidity barrier.

MODEL DEW-7A

PANEL INSTRUMENTS

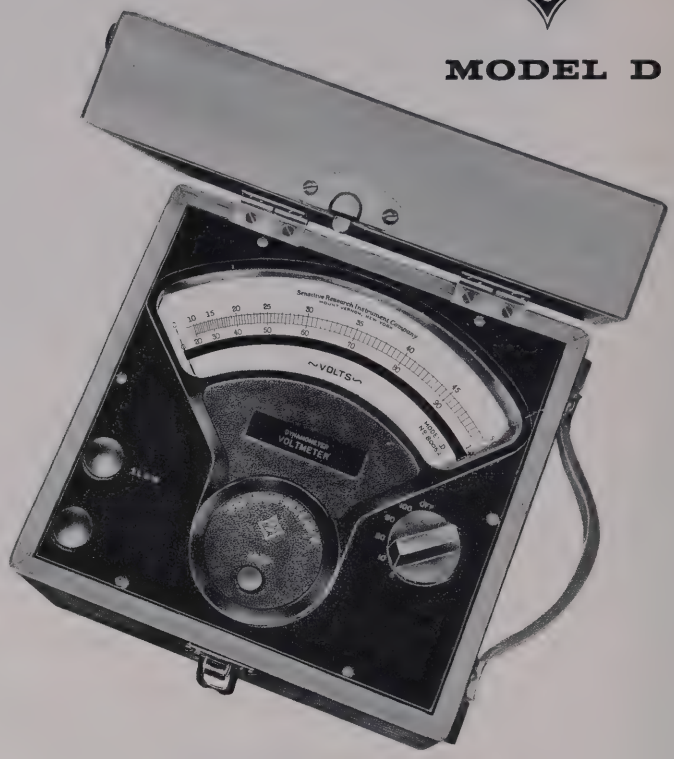
The Model D is also available for vertical panel mounting in the deep EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 258.

Performance characteristics are the same as listed for the portable type.

Specify: Model DEW-5A or DEW-7A and code word of portable instrument having ranges desired.

Price: Add $30.00 to price of code word selected.

MODEL D



The electrodynamometer type of instrument is inherently a rugged, fast acting indicator capable of maintaining highly accurate calibration over the years. Since it is a true RMS measuring instrument, it has great value as a portable laboratory standard. Within its frequency range it is completely unaffected by wave form distortion.

The deflection torque of the electrodynamometer instrument is the average torque produced by the mutual action of the electromagnetic fields created by currents in the fixed and moving coils. The instantaneous torque is proportional to the product of the instantaneous magnitudes of the currents in the fixed field coils and the moving coil. When measuring alternating current, the moving coil torque occurs in surges, two for each cycle of the current. Because the moving element has a time constant that is very long compared to the period of the alternating current, these surges of torque are mechanically averaged.

If the same current flows in the moving coil and fields, or there is a fixed ratio of one to the other, the deflection of the instrument is proportional to the mean square value of current in the coils. The scale contains a root factor and so scale readings are in RMS values. See page 254 for typical dynamometer scale.

With direct current in the coils, the torque is still proportional to the RMS (steady DC) value. Thus the electrodynamometer is an accurate transfer instrument which may be calibrated on direct current and used to measure alternating current. When measuring direct current, maximum accuracy is obtained by reversing polarities and using the average value of the two readings.

All frequency ranges specified are based on sinusoidal waveforms. Harmonic components outside the stated frequency range of the instrument often do not cause appreciable errors in reading, since the response of the instrument does not fall off rapidly with increasing frequency. It is not recommended for frequencies below 15 cycles.

DYNAMOMETER MILLIAMMETERS AND AMMETERS

DYNAMOMETER MILLIAMMETERS

Full Scale Milliamperes	*Approx. Resist. ohms	*Approx. Induct. in Henrys	Scale Div.	D.C. & 25-125 cps Code	Price	D.C. & 25-500 cps Code	Price	D.C. & 25-1000 cps Code	Price	D.C. & 25-2500 cps Code	Price
5/10	3500/2500	3/3	100	DYMISA	$315						
10/20	2000/1000	.63/.16	100	DYMIFF	305	DYMIFF-5	$325				
15/30	1375/600	.55/.14	150	DYMILL	280	DYMILL-5	295				
30/60	300/175	.18/.045	120/150	DYMIPP	280	DYMIPP-5	295				
50/100	100/85	.07/.018	100	DYMITT	280	DYMITT-5	295	DYMITT-10	$305	DYMITT-25	$320
75/150	60/30	.08/.02	150	DYMIJE	280	DYMIJE-5	295	DYMIJE-10	305	DYMIJE-25	320
150/300	15/9	.017/.004	150	DYMIKS	280	DYMIKS-5	295	DYMIKS-10	305	DYMIKS-25	320
250/500	9.8/4.9	.006/.0017	125/100	DYMILE	280	DYMILE-5	295	DYMILE-10	305	DYMILE-25	320
300/600	6.4/2.5	.006/.0017	150/120	DYMIST	280	DYMIST-5	295	DYMIST-10	305	DYMIST-25	320
500/1000	3.5/1.9	.0028/.00007	100	DYMIXE	280	DYMIXE-5	295	DYMIXE-10	305	DYMIXE-25	320

All dynamometer MILLIAMMETERS compensated up to 500 cycles, and the codes DYMITT-10, DYMIJE-10, DYMIKS-10, DYMILE-10 are contained in the Size 11 case (7¾" x 7¾" x 6½"). All other dynamometer MILLIAMMETERS compensated above 500 cycles are contained in the Size 12 case (13¾" x 7½" x 6½").

DYNAMOMETER AMMETERS

Full Scale Amperes	*Approx. Resist. ohms	*Approx. Induct. in Henrys	Scale Div.	D.C. & 25-125 cps		D.C. & 25-500 cps		D.C. & 25-1000 cps		D.C. & 25-2500 cps	
1/2	2.1/.7	2.8/.7 mh	100	DYAMAL	$280	DYAMAL-5	$295	DYAMAL-10	$305	DYAMAL-25	$320
2.5/5	1.1/.48	.6/.15 mh	125/100	DYAMER	280	DYAMER-5	295	DYAMER-10	305	DYAMER-25	320
5/10	.125/.06	.04/.01 mh	100	DYAMIK	280	DYAMIK-5	300	DYAMIK-10	310	DYAMIK-25	360
10/20	.066/.03	.02/.005 mh	100	DYAMOO	280	DYAMOO-5	305	DYAMOO-10	355	DYAMOO-25	375

*** Values for 25-125 cps instruments**

All dynamometer AMMETERS are contained in the Size 12 case excepting the codes DYAMAL and DYAMAL-5.

SINGLE RANGE INSTRUMENT PRICING

Single range instruments available from 5 milliamperes to 20 amperes.

MILLIAMMETERS—Use price of multirange milliammeter whose *lowest* range is the required range and deduct $25 for 25-125 cps instruments. For frequency compensated instruments deduct additionally as follows: 500 cps, $5; 1000 cps, $7; 2500 cps, $15.

AMMETERS—Use price of multirange ammeter whose *highest* range is the required range and follow same procedure as for milliammeters.

FREQUENCY COMPENSATION FOR AMMETERS AND VOLTMETERS

Dynamometer instruments normally furnished for use on DC and 25-125 cycles, can usually be compensated over a greater frequency span depending on the range, sensitivity and accuracy required. The practical limitations are ones of power consumption and increased size and cost. Instruments designed for use over a range of 25-2500 cycles draw considerably more power than those manufactured for use at lower frequencies and/or a narrower span. In some instances, the compensated instrument must be installed in a larger case, or furnished with an external multiplier or shunt box. In a multirange instrument, the ratio of highest to lowest range is of significance inasmuch as the power consumed in the lowest range is multiplied by the ratio factors of the higher ranges (i.e. a voltmeter with a range of 0-15 volts draws about 350 ma, or dissipates 5.25 watts, if compensated from 25-2500 cycles. If ranges of 30/75/150/300 volts are added, the power consumption for each extra range is multiplied by factors of 2/5/10/20 for a dissipation of 10.5/26.5/52.5/105 watts. While such an instrument can be manufactured, it is obviously not practical from the standpoint of efficiency, size and cost).

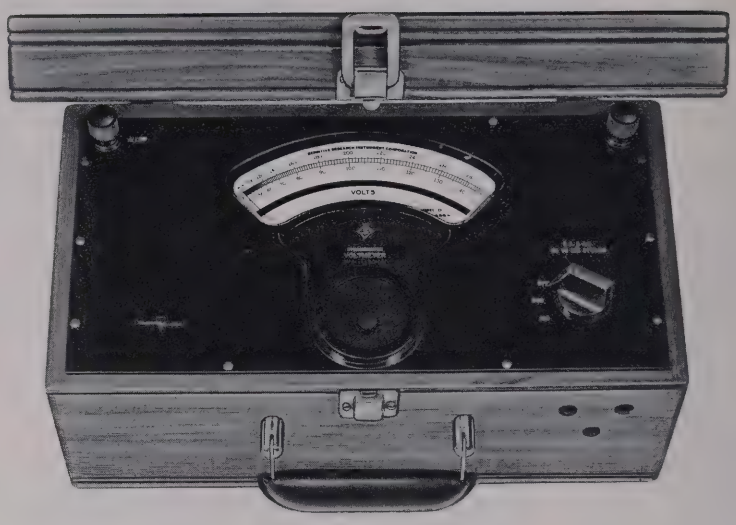
When compensated, no frequency correction factor need be applied to achieve rated accuracy. The compensation is accomplished by introducing a capacitive time constant into the circuit to balance the inductive time constant of the dynamometer and its multiplier resistances. In this way, the impedance of the instrument is substantially constant over the complete range of frequencies for which it is compensated.

Listed above and on page 254 are single and multirange Dynamometer Milliammeters, Ammeters and Voltmeters with their maximum practical frequency span. It is possible to supply special single range instruments for use "at" a particular frequency (i.e. 400 cycles with a span of 380-420 cycles) with less power consumption than if designed for operation over a wider frequency span. Maximum frequency can exceed 2500 cycles in some cases if calibration is "at" a particular frequency. In addition, special instruments with different ranges than listed can be supplied provided their ratios of ranges and sensitivity do not exceed the practical considerations just detailed. Correspondence concerning special instruments is invited.

DYNAMOMETER VOLTMETERS

MODEL D

SPECIFICATIONS



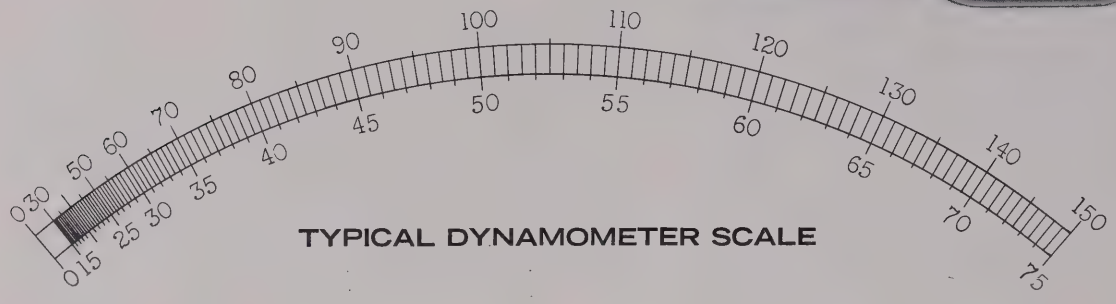
VOLTMETER specifications are as listed on page 252.

SPECIAL RANGES are available within the minimum and maximum ranges listed. External multipliers may be used for extension of ranges beyond 1000 volts. Correspondence is invited.

LEADS supplied for all voltmeters with ranges below 7.5 volts.

RESISTANCES listed below are for 25-125 cycle meters. Higher frequency voltmeters have lower resistances, e.g., at 1000 cycles, resistances decrease by approx. 60%.

PANEL INSTRUMENTS available. See page 252.



TYPICAL DYNAMOMETER SCALE

SINGLE RANGE VOLTMETERS

Full Scale Volts	Approx. Total Resist. Ohms	Scale Div.	D.C. & 25-125 cps Code	Price	D.C. & 25-500 cps Code	Price	D.C. & 25-1000 cps Code	Price	D.C. & 25-2500 cps Code	Price
*1.5	3.5	150	*DYVOSH	$235						
*3	7	150	*DYVOLT	235						
7.5	65	150	DYVOMO	235	DYVOMO-5	$245	DYVOMO-10	$255		
15	200	150	DYVONI	235	DYVONI-5	245	DYVONI-10	255	DYVONI-25	$265
30	400	150	DYVOOK	235	DYVOOK-5	245	DYVOOK-10	255	DYVOOK-25	265
50	1300	100	DYVOPA	235	DYVOPA-5	245	DYVOPA-10	255	DYVOPA-25	265
75	2500	150	DYVORI	235	DYVORI-5	245	DYVORI-10	255	DYVORI-25	265
100	5000	100	DYVOST	235	DYVOST-5	245	DYVOST-10	255	DYVOST-25	265
150	15000	150	DYVOTO	235	DYVOTO-5	248	DYVOTO-10	258	DYVOTO-25	268
300	30000	150	DYVOWI	240	DYVOWI-5	250	DYVOWI-10	260	DYVOWI-25	270
500	50000	100	DYVOBA	249	DYVOBA-5	259	DYVOBA-10	269	DYVOBA-25	279
750	75000	150	DYVOCO	254	DYVOCO-5	264	DYVOCO-10	274	DYVOCO-25	284
1000	90000	100	DYVODI	259	DYVODI-5	269	DYVODI-10	279	DYVODI-25	289

All single range dynamometer voltmeters compensated for 2500 cps, and all single range instruments over 100 volts compensated for 1000 cps are contained in the Size 12 case (13¾" x 7½" x 6½"). Other single range instruments are in the Size 11 case (7¾" x 7¾" x 6½").

MULTIRANGE VOLTMETERS

Full Scale Volts	Scale Div.	D.C. & 25-125 cps		D.C. & 25-500 cps		D.C. & 25-1000 cps		D.C. & 25-2500 cps	
*1.5/3	150	*DYVOSP	$265						
7.5/15	150	DYVOTI	255	DYVOTI-5	$280				
30/75	150	DYVOLL	265	DYVOLL-5	280	DYVOLL-10	$290		
75/150	150	DYVOBY	268	DYVOBY-5	283	DYVOBY-10	293	DYVOBY-25	$307
150/300	150	DYVOCA	270	DYVOCA-5	285	DYVOCA-10	295	DYVOCA-25	310
300/600	150/120	DYVOXY	279	DYVOXY-5	294	DYVOXY-10	304	DYVOXY-25	319
300/750	150	DYVOPX	282	DYVOPX-5	297	DYVOPX-10	307	DYVOPX-25	322
75/150/300	150	DYVOKA	285	DYVOKA-5	305	DYVOKA-10	320		
150/300/600	150/120	DYVOLP	294	DYVOLP-5	314	DYVOLP-10	329		
150/300/750	150	DYVOUT	297	DYVOUT-5	317	DYVOUT-10	332		
7.5/15/30/75	150	DYVOOM	305	DYVOOM-5	340				
10/20/50/100	100	DYVDOM	305	DYVDOM-5	340				
15/30/75/150	150	DYVOOT	315	DYVOOT-5	350				
30/75/150/300	150	DYVOOS	317	DYVOOS-5	352				
75/150/300/750	150	DYVOOZ	329	DYVOOZ-5	364				

All multirange dynamometer voltmeters are contained in the Size 12 case. Multirange instruments have a constant ohms per volt on all ranges which is the same as their lowest range.

***Codes DYVOSH, DYVOLT and DYVOSP, accuracy .25% at 60 cps and .5% from 25 to 70 cps.**

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

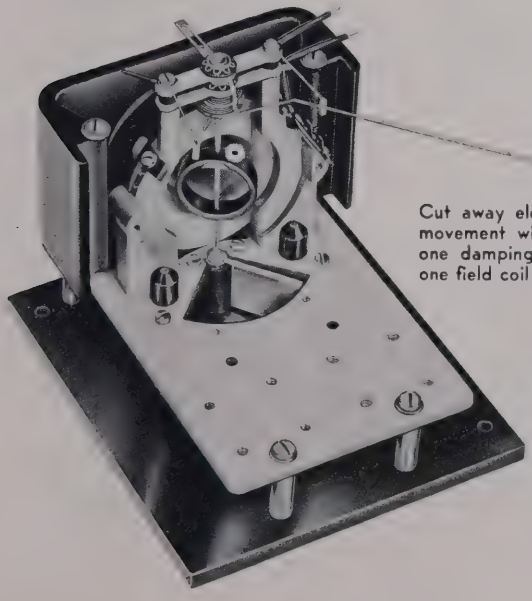
ACCURACY	.5% of full scale
FREQUENCY	DC & 25-125 cps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2–3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Single & double range binding posts only; three ranges and above switch controlled
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite: 5-5/16" x 5-1/8" x 4-1/2" deep; carrying handle
APPROX. WEIGHT	5 lbs net; 8 lbs shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

The University Model Dynamometer is a moderately priced AC/DC electrical indicating instrument employing the same operating principles as the Model D described on pages 252-254. It makes available in a small portable general purpose case the principal features of the dynamometer type construction.

The moving element is located in a compartment that is isolated from the main network of wiring and resistors. This section of the instrument can therefore be serviced without exposing the moving element to contamination in the atmosphere. In addition it is relatively free from the effects of self-heating by its multipliers and can be used for continuous duty on higher volt ranges without a circuit interrupter.

Although the scale length is 4 inches, because the scale characteristics are approximately square law, the upper 60% is greatly expanded. Therefore the scale divisions are wider, or resolution is markedly increased, in the area where readings are most meaningful. The scale is compressed at the lower end where it is not good instrumentation practice (even with a linear scale) to attempt high accuracy measurements.



Cut away electrodynamometer movement with part of shield, one damping vane cover, and one field coil removed.

UNIVERSITY MODEL

AMMETERS

Full Scale Amperes	Scale Div.	Code	Price
1.5/3	75/60	UDAYBO	$182.00
2.5/5	125/100	UDYADI	182.00
5/10	100	UDYAFO	182.00

For single range instruments deduct $10.00.

MILLIAMMETERS

Full Scale Milliamperes	Approx. Resistance Ω	Scale Div.	Code	Price
10/20	2000/1000	100	UDYMAE	$190.00
15/30	1375/600	75/60	UDYMET	175.00
30/60	300/175	60	UDYMOO	170.00
50/100	100/85	100	UDYMUS	170.00
75/150	60/30	75	UDYMIP	170.00
150/300	15/9	75/60	UDYMAT	170.00
250/500	9.8/4.9	125/100	UDYMEO	170.00
300/600	6.4/2.5	60	UDYMIX	170.00
500/1000	3.5/1.9	100	UDYMOY	170.00

For single range instruments deduct $10.00.

VOLTMETERS

Full Scale Volts	Approx. Ohms per volt	Scale Div.	Code	Price
75/150	100	75	UDYVUR	$174.00
150/300	100	75/60	UDYVOX	175.00
300/750	100	60/75	UDYVAP	178.00
30/75/150	13.3	60/75	UDYVAX	198.00
75/150/300	100.	60/75	UDYVIS	200.00
150/300/600	100.	60/75	UDYVUL	202.00
7.5/15/30/75	3.3	60/75	UDYOKI	218.00
10/20/50/100	10.	100	UDYOPA	218.00
15/30/75/150	13.3	60/75	UDYOBI	220.00
30/75/150/300	13.3	60/75	UDYOCK	223.00

SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
FREQUENCY	See note A below.
TYPE	Moving iron
SCALE	Hand drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2—3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Single & double range binding posts only; three ranges or more switch controlled.
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾"x7¾"x4¾" h.; black bakelite panel; hinged cover; carrying handle.
APPROX. WEIGHT	7 lbs. net; 11 lbs. shipping.

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

PANEL INSTRUMENTS

The Model MI is also available for vertical panel mounting in the shallow EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 258.

Performance characteristics are the same as listed for the portable type, except frequency compensation cannot be provided above 800 cycles.

Specify: Model MIEW-5A or MIEW-7A and code word of portable instrument having ranges desired.

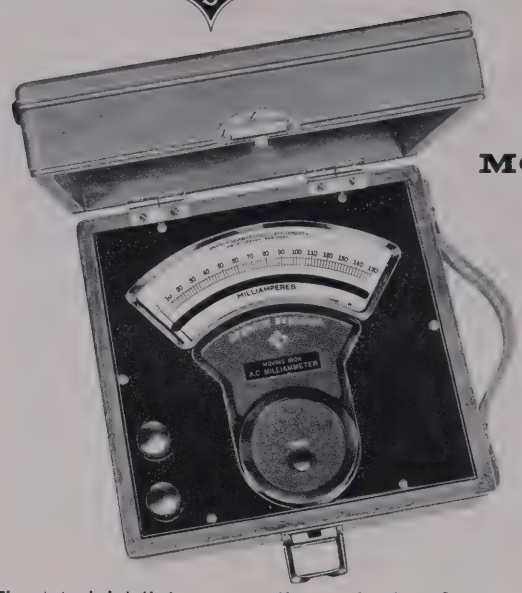
Price: Add $25.00 to price of code word selected.

MILLIAMMETERS (See Note A)

Milliamps.	Approx. Res. Ω	Scale Div.	Code	Price
10	1800	100	MIMAAH	$145.00
15	1050	150	MIMILZ	145.00
30	300	150	MIMILO	145.00
50	90	100	MIMILK	145.00
75	40	150	MIMILI	145.00
100	24	100	MIMIST	145.00
150	12	150	MIMIKO	145.00
300	3.5	150	MIMIBU	145.00
500	1.0	100	MIMICK	145.00
750	.38	150	MIMIFA	145.00
75/150	40/20	150	MIMIOK	166.00
150/300	12/6	150	MIMIRT	166.00
250/500	4/2	125/100	MIMIKY	166.00
500/1000	1/.5	100	MIMIOT	166.00

AMMETERS (See Note A)

Amperes	Scale Div.	Code	Price
1	100	MIAMAB	$145.00
2	100	MIAMEC	145.00
3	150	MIAMID	145.00
5	100	MIAMOF	145.00
10	100	MIAMUJ	145.00
15	150	MIAMO	145.00
20	100	MIAMFA	145.00
25	125	MIAMJY	145.00
30	150	MIAMKS	150.00
50	100	MIAMLY	155.00
1.5/3	150	MIAMOO	168.00
2.5/5	125/100	MIAMAS	168.00
5/10	100	MIAMII	168.00
10/20	100	MIAMAU	168.00



MODEL MI

The Model MI is an excellent selection for use as an AC electrical indicating instrument when price, ruggedness and good accuracy over a low frequency range are primary considerations. The indicating mechanism employed is a moving iron movement which can withstand unusual physical abuse and relatively large electrical overloads. In fact, it is virtually impossible to distort the pointer by an electrical overload. All moving iron types have scales that are almost linear over their upper 85%.

VOLTMETERS Frequency, 25-125 cycles (See Note A)

Volts	Approx. Res. Ω	Scale Div.	Code	Price
** 7.5	50	150	MIVOHO	$150.00
** 10.0	90	100	MIVODA	150.00
** 15.0	170	150	MIVOFY	150.00
30	425	150	MIVOLT	150.00
50	1150	100	MIVOMO	150.00
75	2700	150	MIVOPI	150.00
150	5500	150	MIVOSY	150.00
250	19000	125	MIVOTE	152.00
300	22500	150	MIVOVA	154.00
500	38000	100	MIVOBS	156.00
** 7.5/15		150	MIVOJI	161.00
** 10/50		100	MIVONA	161.00
30/75	*Multirange instruments have a constant ohms per volt on all ranges which is the same as their lowest range.*	150	MIVOZR	161.00
50/100		100	MIVOEP	161.00
*125/250		125	MIVOIN	163.00
*150/300		150	MIVOOM	165.00
*300/750		150	MIVOUT	167.00
* 30/75/150		150	MIVOYA	171.00
* 50/100/250		100/125	MIVOYO	173.00
* 75/150/300		150	MIVOYI	175.00
*100/200/500		100	MIVOYU	177.00
*150/300/750		150	MIVOYE	184.00

NOTE A — FREQUENCY: Current instruments are normally calibrated at 60 cycles. However, if specified by the customer, calibration may be done at 400 cycles. The following accuracies apply:

MILLIAMMETERS calibrated at:
60 cps. — ½% 25-125 cps.; ¾% 125-500 cps.
400 cps. — ½% 300-500 cps.; ¾% 25-300 cps.

AMMETERS calibrated at:
60 cps. — ½% 25-125 cps.; 1% 125-500 cps.
400 cps. — ½% 300-500 cps.; 1% 25-300 cps.

VOLTMETERS: Above 15 volts, voltmeters can be supplied compensated for use from 25 to 1000 cycles, at additional cost. Voltmeters compensated for 25-1000 cycles, will be supplied at a lower resistance than shown above.

*Edgewise panel instruments supplied with external multipliers mounted on rear.

** *.5% accuracy for 50-70 cycles only.*

MODEL NSI

SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
FREQUENCY	Voltmeters 25-125 cps.; ammeters and milliammeters refer to note A below.
TYPE	Moving iron
SCALE	Hand drawn; 6"; almost linear; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Polished steel
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts only
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 7½" x 6¾" x 3½" deep; black bakelite panel; carrying handle
APPROX. WEIGHT	4½ lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

If diamond pivots are desired add $30.00 to list price.

THE MODEL NSI moving iron type instrument is a low cost AC electrical indicating instrument based on the same operating principles as the Model MI described on page 256. It makes available the principal features of the moving iron design in a portable general purpose case.

The moving element is located in a compartment that is isolated from the main network of wiring and resistors. The resistors and/or shunts can therefore be serviced without danger of accidentally damaging the moving element, or exposing it to dust particles. In addition the Model NSI is relatively free from the effects of self heating by its multipliers and can be used for continuous duty up to *500 volts without requiring a press to read switch.

SPECIAL MULTIRANGE VOLTMETER

Full Scale Volts	Scale Div.	Code	Price
3/7.5/15/30/75/150/300/750	50	NSIVOMUL	$225.00

This is a transformer coupled instrument for 50-125 cycle use only. Switch controlled.

VOLTMETERS (25-125 cycles)

Volts	Approx. Resistance Ohms	Scale Div.	Code	Price
7.5	25	150	NSIVOB	$125.00
10	40	100	NSIVOC	125.00
15	75	150	NSIVOD	125.00
30	120	150	NSIVOE	125.00
120	5500	120	NSIVOF	125.00
150	7500	150	NSIVOG	125.00
300	22,000	150	NSIVOJ	130.00
*500	35,000	100	NSIVOK	130.00
*750	52,500	150	NSIVOL	130.00
7.5/15	25/50	150	NSIVOM	135.00
15/30	75/150	150	NSIVOO	135.00
75/150	2700/5400	150	NSIVOP	135.00
150/300	7500/15,000	150	NSIVOR	135.00
*300/600	22,000/44,000	150/120	NSIVOT	135.00
30/75/150	120/300/600	150	NSIVOV	147.00
75/150/300	2700/5400/10,800	150	NSIVOW	147.00
*100/200/500	6600/13,200/33,300	100	NSIVOX	147.00
*150/300/600	7500/15,000/30 000	150/120	NSIVOY	147.00
*150/300/750	7500/15,000/37,500	150	NSIVOZ	147.00

*** Press to read switch provided for ranges of 500 volts and above. These ranges not for continuous operation.**

AMMETERS (See Note A)

Amperes	Scale Div.	Code	Price
1	100	NSIAMP	$120.00
2	100	NSIAMB	120 00
3	150	NSIAMI	120.00
5	100	NSIAMO	120.00
10	100	NSIAMU	120.00
1.5/3	150	NSIAMA	140.00
2.5/5	125/100	NSIAME	140.00
5/10	100	NSIAMY	140.00

MILLIAMMETERS (See Note A)

Milliamps.	Approx. Res. Ohms	Approx. Inductance mh	Scale Div.	Code	Price
10	1800	3130	100	NSIMIL	$120.00
15	1050	900	150	NSIMIM	120.00
30	307	235	150	NSIMIN	120.00
50	90	140	100	NSIMIO	120.00
75	40	90	150	NSIMIP	120.00
100	24	50	100	NSIMIR	120.00
150	10	26	150	NSIMIS	120.00
300	2.6	5.5	150	NSIMIT	120.00
500	.94	1.8	100	NSIMIV	120.00
750	.4	9	150	NSIMIZ	120.00
50/100	90/45	140/35	100	NSIMAA	140.00
75/150	40/20	90/24	150	NSIMEE	140.00
150/300	10/5	26/6.5	150	NSIMII	140.00
250/500	3.6/1.8	7/1.8	125/100	NSIMOV	140.00
500/1000	2/1	1.8/.45	100	NSIMOY	140.00

NOTE A—FREQUENCY: AC Milliammeters and Ammeters are frequency compensated. Rated accuracy is maintained 25-125 cps. Frequency influence will not exceed .2% additional for 125-500 cps.

EDGEWISE PANEL CASE DIMENSIONS

DYNAMOMETER AND MOVING IRON INSTRUMENTS

GENERAL INFORMATION

The Model D (Pages 252-254) and Model MI (Page 256) are available for flush, vertical panel mounting in the EW-5A and EW-7A cases as per mounting dimensions and specifications listed below. The principal feature of an edgewise panel design is that any portable horizontal type can be converted for panel mounting without sacrificing accuracy or sensitivity for an equivalent scale length. Pivots ride in a normal upright position and hence pivot roll or instability is virtually eliminated.

The case is of cast aluminum with a black wrinkle finish. Electrical specifications detailed on above referenced pages apply to the edgewise panel types. Instruments that are mounted in the EW-7A case have increased burdens by approximately 20% because of this model's longer scale length. The UNIVERSITY model dynamometer is not available as an edgewise panel instrument.

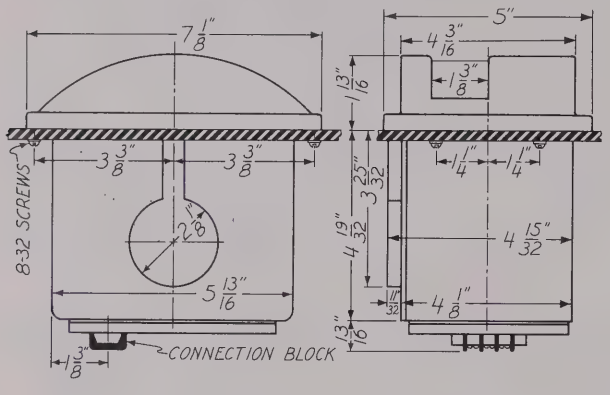
NOTE 1: Edgewise panel cases are NORMALLY furnished with terminal strips. However, some instruments, such as high current types, demand binding posts and are furnished that way.

NOTE 2: Front zero adjusters are standard on the deep and shallow EW-5A and EW-7A cases.

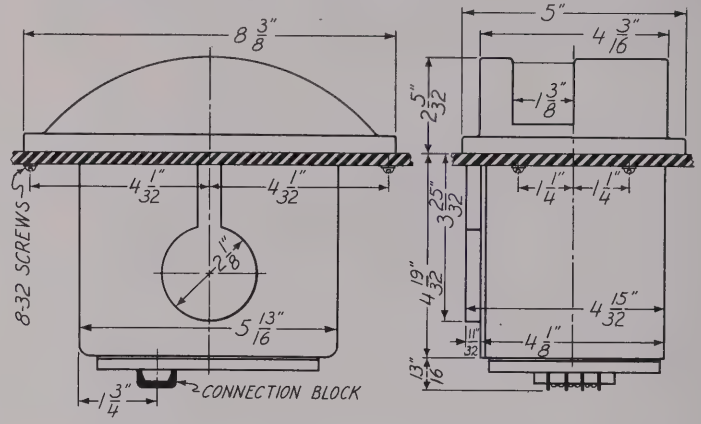
NOTE 3: Where switch control is available in the EW-5A & EW-7A deep cases the same type of switch is utilized as is illustrated in the dimensional drawings of the shallow cases.

MODEL D, DYNAMOMETER INSTRUMENTS

Current instruments are supplied with binding posts or terminal strips on the rear of the case. Voltmeters with 3 ranges or more are supplied with range switch in front of case. For most multi-range instruments of 3 ranges or more, external multipliers (not more than 2½" deep) are supplied mounted on the back of the instrument because of limited space in the edgewise case. Prices include these multipliers. For mounting in EW-5A case, or EW-7A case, add $30 to the price of the Model D.



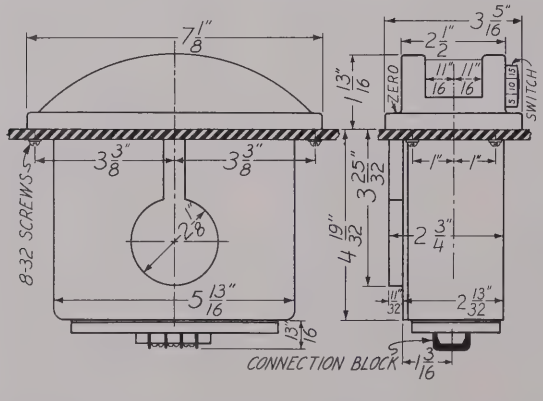
DEW-5A DEEP CASE, Scale Length 5"



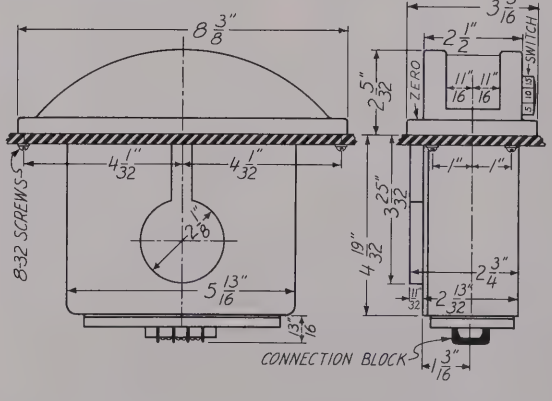
DEW-7A DEEP CASE, Scale Length 7"

MODEL MI, MOVING IRON INSTRUMENTS

For complete specifications on moving iron voltmeters, milliammeters, and ammeters see page 256. All instruments are supplied with binding posts or terminal strips only. Voltmeters with a range of 250 volts or higher are furnished with external multipliers mounted on the back of the instrument because of limited space in the panel mounting case. Prices include these multipliers. Where external multipliers are supplied the instrument may be used for continuous duty and no push-button or "Press to Read" is necessary. For mounting in EW-5A case, or EW-7A case add $25 to the price of the Model MI.



MIEW-5A SHALLOW CASE, Scale Length 5"



MIEW-7A SHALLOW CASE, Scale Length 7"

Prices and specifications subject to change without notice.

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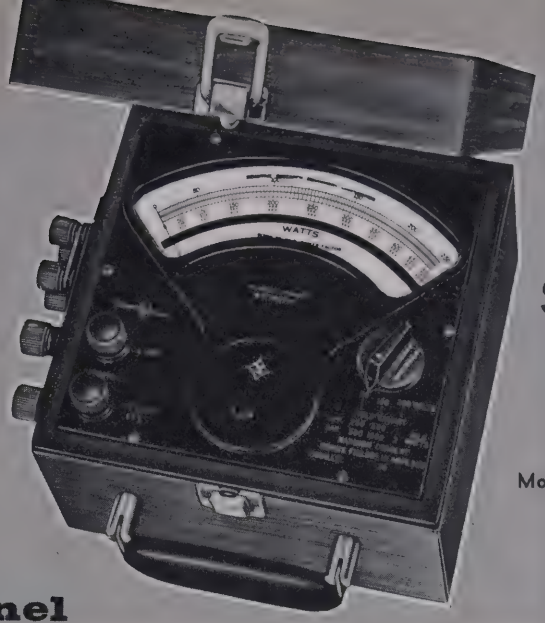
Model PDWEW-5



Model DW

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Portable and Panel

AC/DC SINGLE PHASE and POLYPHASE ELECTRODYNAMOMETER WATTMETERS

UNIVERSAL AC TEST SETS, POWER FACTOR INSTRUMENTS, VOLT-AMP-WATTMETERS

Model	Description	Min. PF	Page
	"About Wattmeters" . . . Application Notes . . . Availability of Special Wattmeters . . . How to Order Wattmeters		302-303
DW	.25% AC/DC Single Phase Wattmeters. 6.3" scale length	50%	304
DLW	.5% AC/DC Single Phase Wattmeters. 5.2" scale length	20%	305
University	.5% and .75% AC/DC Single Phase Wattmeters. 4" scale length	20%	306-307
PF	Single Phase Power Factor Instrument. 6.3" scale length		307
PPF	Polyphase Power Factor Instrument. 6.3" scale length		307
VAW	.5% and .75% AC Single Phase Volt-Amp-Wattmeters. 5.2" scale length	50%	308-309
	Discussion of Two Element (or Polyphase) Wattmeters— Application Notes and Circuit Connections		310-311
PDW	.5% AC/DC 2 Element (or Polyphase) Wattmeters. 6.3" scale length	50%	312
PDLW	.75% AC/DC 2 Element (or Polyphase) Wattmeters. 5.2" scale length	20%	313
U60AC	Universal AC Test Set (50-60 cps)	10%	314-315
U400AC	Universal AC Test Set (50-400 cps)	10%	314-315
U1000AC	Universal AC Test Set (DC and 25-1000 cps)	10%	314-315
	Switch Controlling of Single Phase Wattmeters		315
	Mounting Dimensions for Type EW-5A and EW-7A deep cases, and Polyphase EW-5 case		316

Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N.Y.

Symbol of Quality

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

Electrical Measuring Instruments Since 1927

The measurement of AC power is a far more complex problem than indicated by the simple DC relationship P = EI. This formula holds true for AC measurements on an instantaneous basis only, and depending on the relative phase angle between current and voltage, may not be correct for the rms values of each. The actual power becomes EI cosΘ, with Θ being the phase angle between voltage and current for sinusoidal wave forms.

The design of an electrodynamometer type of instrument (see photo on page 303) is well suited for the measurement of AC and DC power. In this design a magnetic field is established by a load current flowing through 2 fixed coils called the current or field coils. Rotating in that field is a moving coil with restoring springs and pointer. The torque of the moving coil is proportional to the current in the moving coil multiplied by the current in the field coils, multiplied again by the cosine of the phase angle of the two currents. If sufficient resistance is added to the moving coil circuit so that its current is proportional to an applied voltage, the operating principle of the instrument is in conformance with the EI cosΘ formula.

the instrument. On the other hand, with the potential circuit connected ahead of the field coils (A-C), the potential being used is greater than that actually applied to the load by the amount of the voltage drop in the field coils. In either case the instrument reads high by the power lost in its own potential *or* current circuits. Each wattmeter has its potential circuit resistance printed on its scale, so that the power it dissipates internally may be easily calculated. The circuit connection which gives the least power lost in the instrument is, of course, preferable.

As seen in Fig. 2 it is possible to have appreciable inductance in the potential circuit (moving coil) and, therefore, a phase angle error which would increase with frequency. This is responsible for the frequency limitation given in the instrument listings. At rated frequencies the phase angle error will ordinarily be less than one or two minutes, a negligible amount. Special instruments can be furnished compensated for a range of frequencies extending higher than catalog listings. In certain instances, even still higher frequency compensation can be furnished on a "single frequency only" basis. Correspondence on such instruments is required.

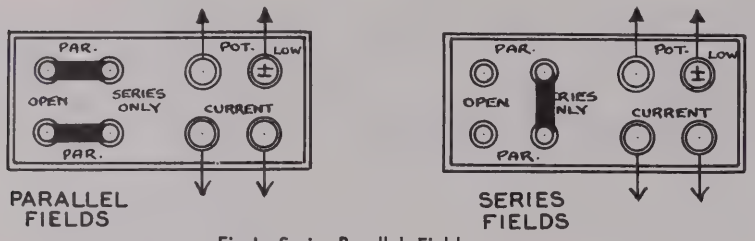


Fig.1. Series-Parallel Fields Range Changing Connections

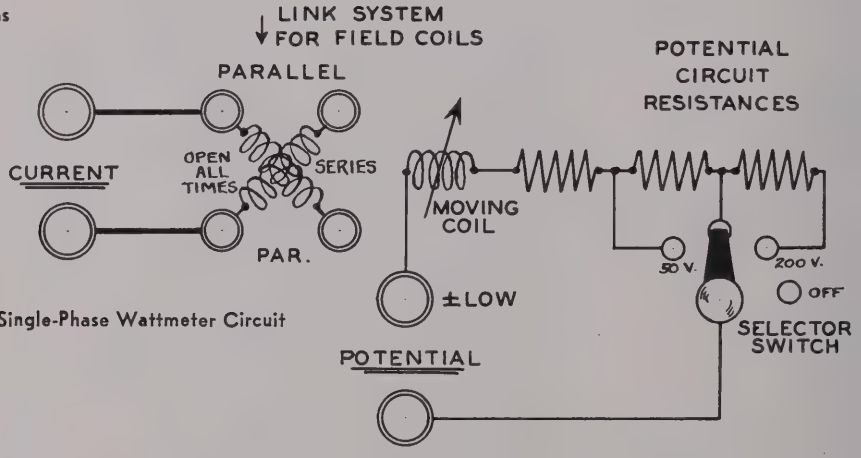


Fig. 2. Fundamental Single-Phase Wattmeter Circuit

The basic circuit of a dynamometer wattmeter is shown in Fig. 2. Several points about this circuit must be considered when ordering a wattmeter. As an example, assume that the angle Θ advances to 90 degrees. CosΘ then becomes 0 and there can be either an infinite current through the field coils or an infinite voltage impressed across the potential circuit, and still no power is consumed. Obviously under these conditions the instrument could be burned out without the pointer moving at all. It is this fact, that the value of cosΘ can assume any value from 1 to 0, that makes it necessary to assign limiting values to the current capacity of a wattmeter. This is dependent, not on the watt rating of an instrument, but upon the current ratings of the field coils. Instruments in which the current capacity of the field coils is much greater than the normal current rating for 0 degrees phase angle (100% power factor) are listed as "Low Power Factor" types. This brochure lists portable wattmeters whose field coils have a current rating sufficient for use at power factors down to 10%.

The load imposed by a wattmeter in a circuit can be a factor in overall accuracy. Fig. 3 shows the two possible ways a wattmeter can be connected. The diagram illustrates that with the potential circuit (moving coil and series resistances) connected to the load side of the field coils (B-C), the current being drawn to actuate the moving coil is added to the load current and is being measured by

On special order most wattmeters can be furnished with compensation for the power consumed in their potential circuit. This is accomplished by a second winding on the field coils of the instrument. In general, compensation of wattmeters is not recommended since it affects their performance. Operation is complicated by the need of a special switch for series and parallel connections. It is better to use compensation external to a standard instrument than to build it into the instrument. A simple circuit for accomplishing this is shown in the Sensitive Research engineering bulletin Electrical Measurements, Volume 27, Number 12, December, 1959, available on request.

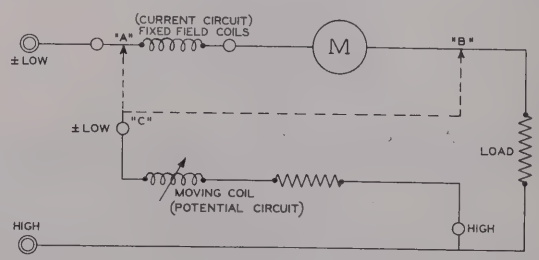


Fig. 3. Circuit Connections for a Single Phase Wattmeter

HOW TO ORDER SPECIAL WATTMETERS

When ordering special wattmeters the ranges required must be given at 100% power factor to satisfy the formula $P = EI \cos\Theta$ ($\cos\Theta$ = unity). If the instrument is to be used at lower power factors than unity (or 100%), the maximum load current at minimum power factor must be stated. The series-parallel field arrangement (see Figs. 1 & 2) employed in dynamometer wattmeters, gives the user a choice of two self-contained current ranges, one of which must be an exact 2 to 1 multiple of the other. Usually two or three potential ranges are furnished, but the only restrictions in this respect are practical ones involving heat dissipation and available space. The frequency span over which each range is to be used, and at what power factors, is also essential ordering information.

An example of how a special wattmeter should be ordered, using arbitrary figures, is as follows:

Accuracy: .25% of full scale
Watt Ranges: 50/100/200/400 watts
Potential Ranges: 50/100/200 volts
Current Ranges: a) Normal I at unity PF; 0-1/2 amps; b) Maximum I at minimum (low) PF; 0-2/4 amps at 50% PF
Frequency: a) DC and 25 cps to 800 cps on 100 and 200 v ranges; b) DC and 25 cps to 400 cps on 50 v range

Note 1: The watt ranges are obtained by cross multiplying all combinations of potential and normal current ranges. In the catalog the watt ranges that are available for each potential range are listed in separate columns. If the volt ranges are in 2 to 1 ratio to each other the same watt range is obtainable for two different values of current and voltage. As an example, using the figures (above) by cross multiplying, ranges of 50/100 watts can be gained from the 50 v range, 100/200 watts from the 100 v range and 200/400 watts from the 200 v range.

Note 2: Overall accuracy is dependent on frequency span and minimum power factor, and both these values must be specified as accurately as possible to achieve an optimum design.

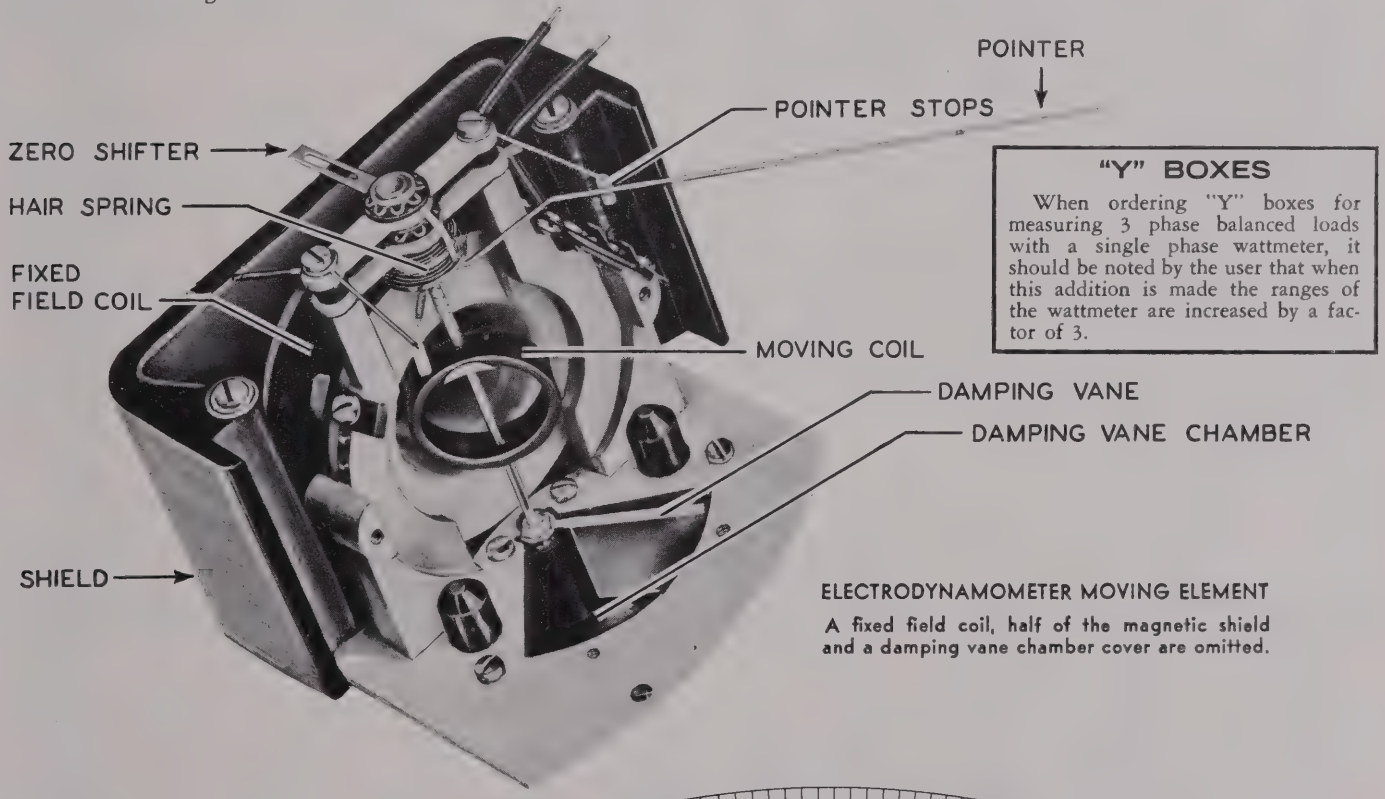
Note 3: The multiplicity of ranges makes it impossible to draw and print scales for all watt ranges. Unless otherwise specified a maximum of two scales is drawn and in most cases this completely satisfies the requirement. In the example given (left) the scale would be drawn with 100/80 divisions and printed 0-50/100/200 watts and 0-400 watts.

Note 4: The maximum current rating of the fixed field coils also is its overload capacity. Using the figures in the example given above, if the instrument is to be used at unity PF its overload rating is 100% (the 1/2 amp ranges can safely tolerate 2/4 amps).

Note 5: All potential ranges are made for continuous use at 60% overload. This fact can be applied to select watt ranges that can be conveniently read on a scale.

The potential circuit sensitivities of all standard wattmeters are high enough to minimize internal heating from continuous duty. Circuit breaking switches, therefore, do not have to be included in their design. They are available where required in special instruments at an additional cost of $25.00.

The same basic information must be given when ordering special polyphase wattmeters as noted above for single phase instruments, with one major additional consideration. When specifying current ranges, the normal and maximum currents must be known in terms of "per phase." The watt ranges of a 2 element wattmeter are calculated by formula for each element as a single phase unit and then doubled to account for the two elements.

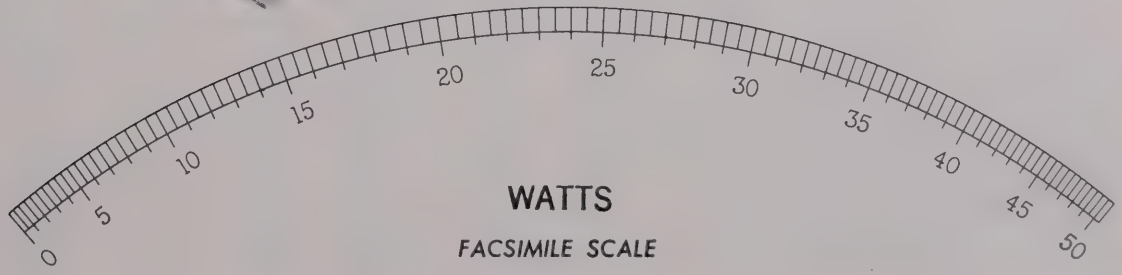


ELECTRODYNAMOMETER MOVING ELEMENT

A fixed field coil, half of the magnetic shield and a damping vane chamber cover are omitted.

"Y" BOXES

When ordering "Y" boxes for measuring 3 phase balanced loads with a single phase wattmeter, it should be noted by the user that when this addition is made the ranges of the wattmeter are increased by a factor of 3.



FACSIMILE SCALE

MODEL DW SINGLE PHASE REFERENCE STANDARD WATTMETERS

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
POWER FACTOR	50% to 100%
FREQUENCY	DC and 25 to 800 cps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Potential circuit switch controlled; current circuit series-parallel binding post connections
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 6⅛" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

OPTIONAL SPECIFICATIONS

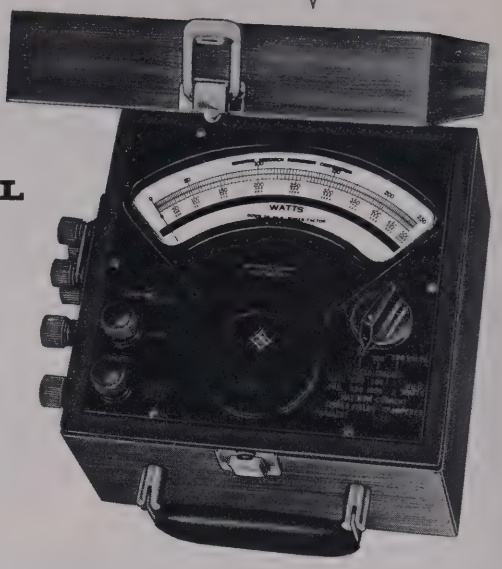
1. Voltage ranges can be increased to 110, 220 and 440 v at no extra charge. Watt ranges remain the same but normal and maximum current ratings decrease in direct proportion. Specify by adding the letter "S" to the code word of the instrument ordered and state the potential ranges required. A wattmeter with two volt ranges can be increased to either 110/220 v or 220/440 v. (Specify ranges desired.) Wattmeters with special ranges and/or scales can be supplied in certain instances. Correspondence necessary.

OPTIONAL ACCESSORIES

1. Voltage ranges can be increased by the addition of external multipliers. Correspondence required. Current ranges can be increased by the use of transformers. The Model TR Type 2 Transformer is recommended for use with wattmeters. (See Section 10.)

2. "Y" boxes can be supplied with single phase wattmeters for the measurement of balanced 3 phase power. The use of a "Y" box is restricted to an individual wattmeter. (See pg. 303 & 311). Price $75.00.

MODEL DW



GENERAL DESCRIPTION

The Model DW is a single phase AC/DC wattmeter for use down to power factors of 50% and frequencies up to 800 cps. Its overall accuracy, ruggedness and stability make it ideally suited for use as either a calibration standard or general purpose testing instrument.

Note: A discussion of single phase wattmeters and their application is included on pages 302-303. It is recommended as a guide in the ordering of wattmeters.

PANEL MOUNTED INSTRUMENTS

The Model DW is available for vertical panel mounting in the deep EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 316. Performance characteristics are the same as listed for the portable type excepting as follows:

1. All ranges are selected from binding posts on the rear of the case. If specified, potential ranges can be supplied switch controlled from the front at an additional cost of $15.00.

2. The Type EW-5A can accommodate a maximum of 100 scale divisions.

Specify: Model DWEW-5A or DWEW-7A and code word of portable instrument having ranges desired.

Price: Add $30.00 to price of code word selected.

RANGES

Note: *Watt ranges are calculated by cross multiplying potential ranges and normal current ranges. To assist the reader, the instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGE			NORMAL (Unity PF) FIELD CURRENT AMPS		MAXIMUM (50% PF) FIELD CURRENT AMPS		Approx. 60 cps	Potential Circuit	Scale		
100 Volts	200 Volts		Series	Parallel	Series	Parallel	va	Approx. Ω/v	Div.	Code	Price
5/10	10/20		.05	.1	.1	.2	.8	180	100	WALER	$315.00
7.5/15	15/30		.075	.15	.15	.3	.5	160	150	WABCL	315.00
15/30	30/60		.15	.30	.3	.6	.4	160	150/120	WAMIS	315.00
25/50	50/100		.25	.50	.5	1.0	.4	150	125/100	WANOT	315.00
37.5/75	75/150		.375	.75	.75	1.5	.8	180	150	WYFAT	315.00
75/150	150/300		.75	1.5	1.5	3.0	.6	160	150	WASUL	315.00
125/250	250/500		1.25	2.5	2.5	5.0	.9	160	125/100	WARAB	315.00
150/300	300/600		1.5	3	3	6	.6	160	150/120	WHACK	320.00
250/500	500/1000		2.5	5	5	10	.75	160	125/100	WASED	325.00
300/600	600/1200		3	6	6	12	1	160	150/120	WAHLN	325.00
500/1000	1000/2000		5	10	10	20	1.3	180	100	WARAC	335.00
50 Volts	**100 Volts**	**200 Volts**									
15/30	30/60	60/120	.3	.6	.6	1.2	1	270	150/120	WEAPA	$330.00
25/50	50/100	100/200	.5	1.0	1.0	2.0	.7	200	125/100	WEALM	330.00
50/100	100/200	200/400	1	2	2	4	1	200	100/80	WEAZO	330.00
75/150	150/300	300/600	1.5	3	3	6	.6	160	150/120	WEAEN	335.00
125/250	250/500	500/1000	2.5	5	5	10	.75	220	125/100	WEAFE	338.00
250/500	500/1000	1000/2000	5	10	10	20	1.3	180	125/100	WEAGZ	348.00

MODEL DLW SINGLE PHASE LOW POWER FACTOR WATTMETERS

MODEL DLW

SPECIFICATIONS AND OPTIONAL LISTINGS

Same as for Model DW on page 304 excepting as follows:
Accuracy: .5% of full scale
Power Factor: 20% to 100%
Frequency: DC and 25 to 500 cps
Scale Length: 5.2"
Codes WARIK, WASOL, WATAK and WATER not available with potential ranges increased. (See "Optional Specifications" on page 304.)

PANEL MOUNTED INSTRUMENTS

The Model DLW is also available for vertical panel mounting in the deep EW-5A (5" scale length) edgewise panel case. For dimensions, see page 316.

Performance characteristics are the same as listed for the portable type excepting:

1. All ranges are selected from binding posts on the rear of the case. If specified, potential ranges can be supplied switch controlled from the front at an additional cost of $15.00.
2. The Type EW-5A can accommodate a maximum of 100 scale divisions.

Specify: Model DLWEW-5A and code word of portable instrument having ranges desired.
Price: Add $30.00 to price of code word selected.

GENERAL DESCRIPTION

The Model DLW is a single phase AC/DC wattmeter designed for use at low power factors. Standard instruments have field coils that are rated for maximum currents down to 20% PF (5 × normal current).

"Special Low Voltage Wattmeters" are listed below with unusually low potential ranges for measuring power as small as 50 milliwatts full scale. The specifications for these wattmeters have been compiled from special instruments manufactured in the past and are illustrative of the various range combinations that can be supplied to fit a particular requirement. Such instruments, however, do not always meet standard performance characteristics for frequency, potential circuit sensitivity and in some cases, overall accuracy. When frequency is other than 60 cps correspondence is necessary.

All Model DLW instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases, made of tough, durable formica, are gasketed to provide an effective dust and humidity barrier. The Model DLW has the same appearance as the Model DW on page 304.

Note: A discussion of single phase wattmeters and their application is included on pages 302-303. It is recommended as a guide in the ordering of wattmeters.

RANGES

Note: *Watt ranges are calculated by cross multiplying potential ranges and normal current ranges. To assist the reader the standard instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGE			NORMAL (Unity PF) FIELD CURRENT AMPS		MAXIMUM (20% PF) FIELD CURRENT AMPS		Approx. 60 cps	Potential Circuit	Scale		
75 Volts	150 Volts		Series	Parallel	Series	Parallel	va	Approx. Ω/v	Div.	Code	Price
*.2/.4	.4/.8		.00266	.00532	.0133	.0266	.12	200	100/80	WARIK	$325.00
**.3/.6	.6/1.2		.004	.008	.02	.04	.12	110	60	WASOL	325.00
.5/1.0	1/2		.0066	.0132	.033	.066	.24	100	100	WAKUP	325.00
1.5/3	3/6		.02	.04	.10	.20	1	140	75/60	WAMOS	325.00
5/10	10/20		.066	.132	.33	.66	1.7	200	100	WAKOH	325.00
7.5/15	15/30		.1	.2	.5	1.0	1.7	180	75/60	WACOT	325.00
10/20	20/40		.133	.266	.666	1.333	1.7	200	100/80	WAROT	325.00
15/30	30/60		.2	.4	1.0	2.0	1.4	160	75/60	WACUM	325.00
20/40	40/80		.266	.532	1.33	2.66	1.2	150	100/80	WAPOT	325.00
37.5/75	75/150		.5	1.0	2.5	5.0	1.5	160	75	WAKER	325.00
75/150	150/300		1.0	2.0	5	10	1.5	200	75/60	WAKIT	330.00
150/300	300/600		2	4	10	20	1.3	160	75/60	WARUS	345.00
300/600	600/1200		4	8	20	40	5.2	210	60	WAAST	355.00
750/1500	1500/3000		10	20	50	100	13	125	75/60	WAOFT	365.00
75 Volts	**150 Volts**	**300 Volts**									
*.2/.4	.4/.8	.8/1.6	.00266	.00532	.0133	.0266	.12	200	100/80	WATAK	$340.00
**.3/.6	.6/1.2	1.2/2.4	.004	.008	.02	.04	.12	110	60	WATER	340.00
.5/1.0	1.0/2.0	2.0/4.0	.0066	.013	.0333	.0666	.24	100	100/80	WATIL	340.00
1.5/3	3/6	6/12	.02	.04	.1	.2	1	140	75/60	WATOS	340.00
5/10	10/20	20/40	.0666	.133	.333	.666	1.7	200	100/80	WATUF	340.00
15/30	30/60	60/120	.2	.4	1	2	1.4	160	75/60	WATYI	340.00
†20/40	40/80	80/160	.266	.532	1.33	2.66	1.2	150	100/80	WATKO	340.00
37.5/75	75/150	150/300	.5	1	2.5	5.0	1.5	160	75/60	WATSA	345.00
75/150	150/300	300/600	1	2	5	10	1.5	200	75/60	WATTI	350.00
150/300	300/600	600/1200	2	4	10	20	1.3	160	75/60	WATBA	360.00
300/600	600/1200	1200/2400	4	8	20	40	5.2	210	60	WATFO	377.00

**DC and 25 - 125 cycle use only* ***DC and 25 - 250 cycle use only* *†Recommended for fluorescent lamp measurements*

SPECIAL LOW VOLTAGE MODEL DLW WATTMETERS

WATT RANGE	POTENTIAL RANGE	Potential Circuit Approx. Ω/v	NORMAL (Unity PF) FIELD CURRENT AMPS Series	Parallel	MAXIMUM (20% PF) FIELD CURRENT AMPS Series	Parallel	Approx. 60 cps va	Scale Div.	Code	Price
.05/.1	20	140	.0025	.0050	.0125	.025	.6	100	WALAM	$465.00
.2/.4/.8/1.6	7.5/15/30	66	.026	.0533	.133	.266	1.6	100/80	WALEK	440.00
.2/.4/.8/1.6	5/10/20	90	.040	.080	.200	.400	4	100/80	WALIS	440.00
.3/.6/1.2	4/8	11	.075	.150	.375	.750	.5	60	WALOB	450.00
1/2	2	15	.500	1.00	2.5	5.0	1	100	WALUT	455.00
2.5/5/10	25/50	70	.100	.200	.50	1.00	1.4	125/100	WALLO	405.00
5/10	10	50	.50	1.00	2.5	5.00	1	100	WALLY	440.00
7.5/15	15	50	.50	1.00	2.5	5.00	1	75	WALLA	435.00
10/20	25	90	.40	.80	2	4.00	1.6	100	WALOO	435.00
10 Watts only	5/10/20	25	(.5 to 2 Amps)		(4 Amps)		2.3	100	WALEA	440.00

UNIVERSITY MODEL SINGLE PHASE COMPACT PORTABLE WATTMETERS

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	a. 50% to 100% PF design: .5% of full scale b. 20% to 100% PF design: .75% of full scale
FREQUENCY	a. 50% to 100% PF design: DC and 25 to 800 cps b. 20% to 100% PF design: DC and 25 to 500 cps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Potential circuit switch controlled; current circuit series-parallel binding post connections
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 5 5/16" x 5 1/8" x 4 1/2" deep; carrying handle
APPROX. WEIGHT	5 lbs. net; 10 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

OPTIONAL SPECIFICATIONS

1. Voltage ranges can be increased to 110, 220 and 440 v at no extra charge, excepting for the codes UWAMOS, and UWAPOT listed under 20% PF instruments. Watt ranges remain the same but normal and maximum current ratings decrease in direct proportion. Specify by adding the letter "S" to the code word of the instrument ordered and state the potential ranges required. A wattmeter with two volt ranges can be increased to either 110/220 v or 220/440 v. (Specify ranges desired.)

2. Wattmeters with special ranges and/or scales can be supplied in certain instances. Wattmeters for use down to 50% PF can be compensated for frequencies up to 800 cps only and down to 15 cps; those rated for use down to 20% PF have an upper frequency limit of 500 cps. A detailed description of how to order special wattmeters is given on pages 302-303. Correspondence is required when ordering special instruments.

PANEL MOUNTED INSTRUMENTS

The University Model cannot be supplied for vertical panel mounting. If specified it can be supplied for horizontal bench mounting at no extra charge.

UNIVERSITY MODEL

GENERAL DESCRIPTION

The University Model is a compact version of the Models DW and DLW described on pages 304-305. It has the advantage of being more economically priced than these instruments while covering essentially the same wide measuring range. All University Model instruments have diamond pivots and sapphire spring mounted jewels to give a virtually friction-free moving element that will withstand abnormal handling.

Note: A discussion of single phase wattmeters and their application is included on pages 302-303. It is recommended as a guide in the ordering of wattmeters.

OPTIONAL ACCESSORIES

1. Voltage ranges can be increased by the addition of external multipliers. Correspondence required. Current ranges can be increased by the use of transformers. The Model TR Type 2 Transformer, with a 5 amp secondary, is recommended for use with wattmeters. Instrument accessories such as multipliers and transformers are described in Section 10.

2. "Y" boxes can be supplied for use with any standard single phase wattmeter for the measurement of *balanced* 3 phase power. They must be ordered with the wattmeter with which they are to be used. If ordered at a later date, the instrument serial number must be given. The use of a "Y" box is restricted to the instrument for which it is supplied. (See pages 303 & 311.) Price $75.00.

RANGES

Note: *Watt ranges are calculated by cross multiplying potential ranges and normal current ranges. To assist the reader, the instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGE 75 Volts	WATT RANGE 150 Volts	NORMAL (Unity PF) FIELD CURRENT AMPS Series	NORMAL (Unity PF) FIELD CURRENT AMPS Parallel	MAXIMUM (20% PF) FIELD CURRENT AMPS Series	MAXIMUM (20% PF) FIELD CURRENT AMPS Parallel	Approx. 60 cps va	Potential Circuit Approx. Ω/v	Scale Div.	Code	Price
†.2/.4	.4/.8	.00266	.00532	.0133	.0266	.12	200	100/80	UWAMOS	$195.00
††.3/.6	.6/1.2	.004	.008	.02	.04	.12	100	60	UWAPOT	195.00
.5/1	1/2	.0066	.0132	.033	.066	.24	100	100	UWARUV	195.00
1.5/3	3/6	.02	.04	.10	.20	1	140	75/60	UWATEX	195.00
5/10	10/20	.066	.132	.33	.66	1.7	200	100	UWAVIH	195.00
7.5/15	15/30	.1	.2	.5	1.0	1.75	160	75/60	UWAWOB	195.00
10/20	20/40	.133	.266	.666	1.333	1.7	160	100/80	UWAXUD	195.00
15/30	30/60	.2	.4	1.0	2.0	1.4	140	75/60	UWABAF	195.00
37.5/75	75/150	.5	1.0	2.5	5.0	1.5	140	75	UWACEG	195.00
75/150	150/300	1.0	2.0	5	10	1.5	160	75/60	UWADIK	195.00
150/300	300/600	2	4	10	20	1.3	140	75/60	UWAFOJ	220.00
300/600	600/1200	4	8	20	40	5.2	180	60	UWAGUK	235.00

† DC and 25 to 125 cps only *†† DC and 25 to 250 cps only*

SINGLE PHASE COMPACT PORTABLE WATTMETERS
POWER FACTOR INSTRUMENTS

UNIVERSITY MODEL RANGES

WATT RANGE 100 Volts	WATT RANGE 200 Volts	NORMAL (Unity PF) FIELD CURRENT AMPS Series	NORMAL (Unity PF) FIELD CURRENT AMPS Parallel	MAXIMUM (50% PF) FIELD CURRENT AMPS Series	MAXIMUM (50% PF) FIELD CURRENT AMPS Parallel	Approx. 60 cps va	Potential Circuit Approx. Ω/v	Scale Div.	Code	Price
5/10	10/20	.05	.1	.1	.2	.7	180	100	UWANAB	$185.00
7.5/15	15/30	.075	.15	.15	.3	.4	160	75/60	UWALOP	185.00
15/30	30/60	.15	.3	.3	.6	.4	150	75/60	UWARIC	185.00
25/50	50/100	.25	.5	.5	1.0	.4	150	125/100	UWAPEB	185.00
37.5/75	75/150	.375	.75	.75	1.5	.8	180	75	UWASOD	185.00
75/150	150/300	.75	1.5	1.5	3.0	.6	160	75/60	UWATUF	185.00
125/250	250/500	1.25	2.5	2.5	5.0	.9	160	125/100	UWAVAG	185.00
150/300	300/600	1.5	3.0	3.0	6.0	.6	160	75/60	UWAVEG	185.00
250/500	500/1000	2.5	5.0	5.0	10.0	.75	160	125/100	UWABIK	185.00
300/600	600/1200	3.0	6.0	6.0	12.0	1	160	60	UWACOL	185.00
500/1000	1000/2000	5.0	10.0	10.0	20.0	1.3	180	100	UWADUM	195.00
50 Volts	**100 Volts**	**200 Volts**								
15/30	30/60	60/120	.3	.6	.6	1.2	1	270	75/60	UWAKAY	$210.00
25/50	50/100	100/200	.5	1.0	1.0	2.0	.7	200	125/100	UWABAT	210.00
50/100	100/200	200/400	1.0	2.0	2.0	4.0	1	200	100/80	UWACES	210.00
75/150	150/300	300/600	1.5	3.0	3.0	6.0	.6	160	75/60	UWADIR	210.00
125/250	250/500	500/1000	2.5	5.0	5.0	10.0	.6	210	125/100	UWAFOV	210.00
250/500	500/1000	1000/2000	5.0	10.0	10.0	20.0	1.3	230	125/100	UWAGUX	218.00

Special Multirange Low Power Factor Wattmeter

A special 10 range wattmeter with watt ranges completely switch controlled can be supplied for use down to 20% PF. The instrument consists of a University Model wattmeter (and conforms to the specifications of this model unless otherwise noted) mounted in a 13¾" x 7½" x 6⅜" formica case with hinged cover and handle. Approx. wt. 12 lbs. net; 20 lbs. shipping.

Accuracy is .75% when used down to 50% PF and 1% when used below 50% PF down to 20% PF. Approximate burden at 60 cps is 4.5 va at maximum current. Potential circuit sensitivity is approximately 80 Ω/v. Normal current ranges at unity PF are .2/.4 amps; maximum currents are 2/4 amps. Scale has 100/80 divisions printed 0-5/10/20 and 0-40 watts. Frequency range 50 to 1000 cps.

RANGES

SERIES FIELDS Max. Volts	Amps	Watts	PARALLEL FIELDS Max. Volts	Amps	Watts
12.5	2	2.5	12.5	4	5
25	2	5	25	4	10
50	2	10	50	4	20
100	2	20	100	4	40
200	2	40	200	4	80

The instrument may be used down to power factors of 10% with reproducible results. Accuracy is 3% or better at 10% PF.

Code UWAMAT Price $625.00

SINGLE AND 3 PHASE POWER FACTOR INSTRUMENTS

MODEL PF SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	±.005 PF
PF RANGE	.5-1-.5 PF
FREQUENCY and VOLTAGE RANGE	60 and/or 400 cps. 115 and/or 230 v (+10% to −30%) Instruments supplied with two voltage ranges for use at a single frequency, or a single voltage range for use at two frequencies. User has choice of voltage ranges and frequencies listed.
CURRENT RANGE	Choice of 2.5/5 amps or 5/10 amps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Potential circuit switch controlled; current circuit series-parallel binding post connections
CASE	Formica 7¾" x 7½" x 6⅛" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

MODEL PF

The Model PF is a single phase portable electrical indicating instrument to measure power factors from 50% lead to 50% lag. When ordering, frequency, voltage and current ranges desired must be given in accordance with data listed in the specification table. Operation is within specifications for inputs of +10% to −30% of 115 v and/or 230 v.

Code PFISP Price $625.00

MODEL PPF

The Model PPF is a polyphase instrument that measures the power factor of balanced 3 phase loads only. It has the same specifications as the Model PF described above except it incorporates voltage ranges of 115 and/or 230 v and can operate at any frequency between 50 and 500 cps. When ordering, specify whether for 2 or 3 phase, 3 or 4 wire circuits, and current ranges, voltage ranges and frequency span desired. Price includes a single voltage range only. If a second range is desired, add $15.00.

Code PFIPP Price $595.00

PANEL MOUNTED INSTRUMENTS

The Models PF and PPF are also available for vertical panel mounting in the deep EW-7A (7" scale length) edgewise panel case. For dimensions, see page 316.

Performance is the same as listed for the portable.

Specify: Model PFEW-7A or PPFEW-7A and code word of portable instrument.

Price: Add $30.00 to price of code word selected.

VOLT-AMP-WATTMETER

MODEL VAW

SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	Current and voltage: .5% of full scale Watts: .75% of full scale
POWER FACTOR	50% to 100%
FREQUENCY	Code VOLTAWATT: 50 to 125 cps Code VOLTOWATT: 50 to 800 cps
TYPE	Transformer-coupled electrodynamometer
SENSITIVITY	Potential circuit 100 Ω/v
SCALE	Hand drawn; 5.2"; anti-parallax mirror
SCALE DIVISIONS	Two 100 div. scales. Watt scale printed 0-500/100 Volt and ampere scale printed 0-10/50
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled excepting 10 ma range on separate binding post
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	12 lbs. net; 20 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

GENERAL DESCRIPTION

The Model VAW, Volt-Amp-Wattmeter, is a multirange transformer-coupled indicating instrument that (1) makes tare-free measurements of AC power, voltage and current, (2) measures all circuit parameters without the necessity of changing circuit connections, (3) has a field current rating for use down to 50% PF or 100% overload and (4) is completely self-contained in a standard portable case.

All uncompensated wattmeters read high by the power consumed in their potential circuit, and in those cases where voltage sensitivity is low, or low values of wattage are to be measured, this can be a considerable factor in overall accuracy. Compensation is accomplished by incorporating a special winding on the internal current transformer. By connecting the potential circuit directly across the load, tare-free compensated measurements can be made.

The Model VAW is particularly valuable as a portable measuring instrument for field use. Operation is simplified by making all ranges switch controlled. Both range combinations are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases made of tough, durable formica, are gasketed to provide an effective dust and humidity barrier.

PANEL MOUNTED INSTRUMENTS

The Model VAW is also available for vertical rack panel mounting. The indicator is housed in a Type EW-5A edgewise panel case with a 5" scale length and installed in a 19" x 7" x 5/16" black bakelite panel. Edgewise panel instruments are described on page 316. Specify as follows:

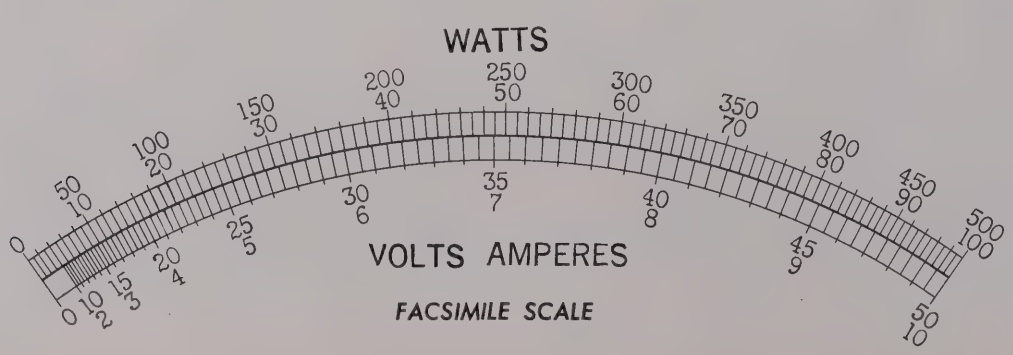
Model	Code	Price
VAWEW-5A	VOLTAWATT	$550.00
	VOLTOWATT	575.00

RANGES

Watts	Volts	Normal Amps (Unity PF)	Max. Amps (50% PF)	Frequency Range	Code	Price
12.5/25/50/100/125/200/250/500/1000/2000/2500/5000	25/50/100/200/500 (100 ohms per v)	.5/1/5/10	1/2/10/20	50-125 cps	VOLTAWATT	$470.00
50/100/200/250/500/1000/2000/2500/5000	100/200/500 (100 ohms per v)	.5/1/5/10	1/2/10/20	50-800 cps	VOLTOWATT*	$495.00

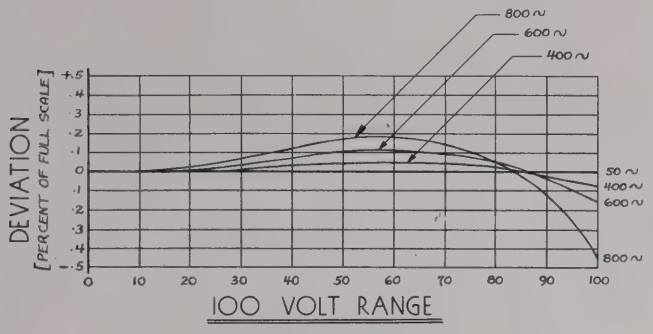
Note 1: Each instrument contains a 10 ma current range on a separate binding post. This range cannot be used for watt measurements.

******The Code VOLTOWATT is guaranteed to make watt measurements within rated accuracy when used at (1) 50 to 125 cps and 50% to 100% PF and (2) 50 to 800 cps and 100% PF. At 400 cps, 50% PF, accuracy is 1.5% and at 800 cps, 50% PF, accuracy is 3%.*



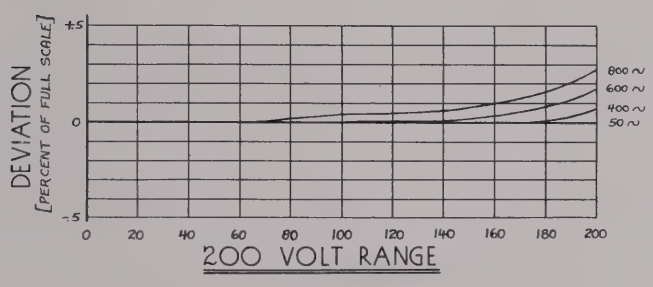
FREQUENCY RESPONSE OF THE VOLT-AMP-WATTMETER

In response to requests for additional information as to the approximate direction and amount of the various errors which might be encountered in the use of the Code VOLTO-WATT (25 to 800 cps) at different frequencies and power factors, the accompanying data was compiled from a single production run of instruments. The figures A through E show the extremes of the errors encountered. *NOTE: These figures are not intended to be used for correction curves nor are they to be considered to extend the basic accuracy guarantees; they are only a general indication of what can be expected.*

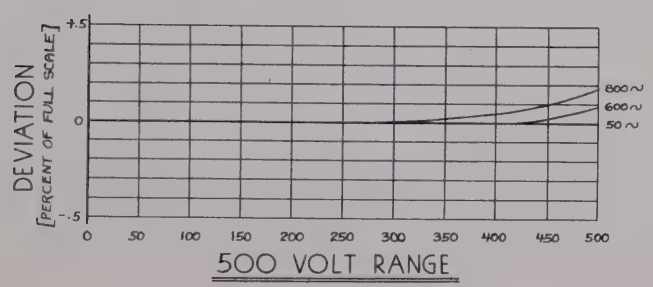


(A)

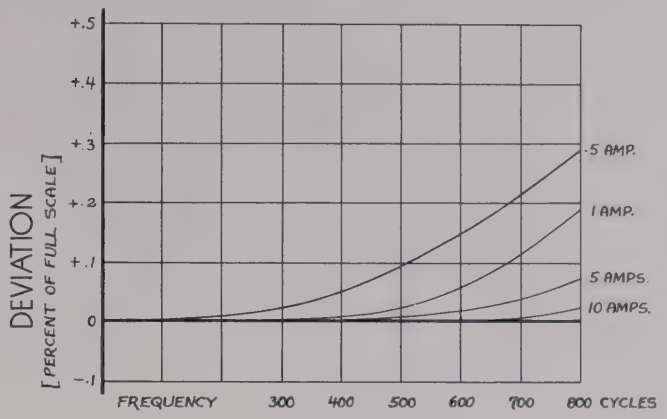
Fig. A is a plot of the lowest voltage range errors. These are plots of error vs. scale reading because in any dynamometer instrument on AC, there is of necessity an impedance variation with pointer deflection due to the variation in mutual inductance of the fields and moving coils. The frequency compensation has to be done on an average inductance basis and is perfect at only a single point. These curves represent the poorest of the group and the best instrument has approximately half of these errors. The shape of the curves is characteristic, however. Fig. B and Fig. C show errors for the higher volt ranges where the additional series R washes out most of the inductive errors.



(B)

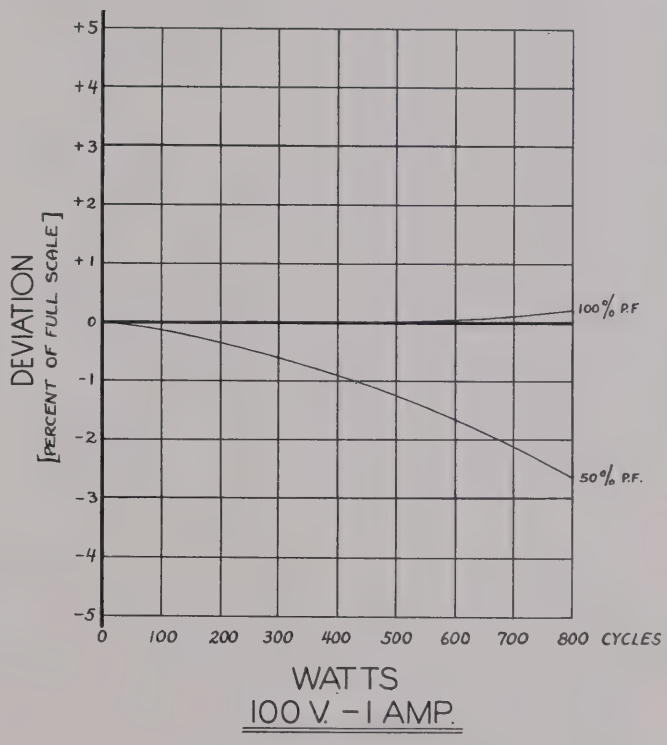


(C)



(D)

Fig. D shows plots of the various current ranges against frequency and these curves can be used for any position on the scale as the inductance variations have a negligible effect on the current readings.



(E)

Fig. E shows a similar plot of wattmeter errors versus frequency. The curve labeled 100% power factor shows comparable errors with the volts and amperes curves. The scale factors are changed to accommodate the greater errors encountered. The curve marked 50% power factor shows markedly greater errors than at 100%. These errors are primarily due to phase angle errors of the current transformer. Such errors are negligible at or near zero degree (100%) but become very significant at lower power factors. Intermediate values of power factor can be expected to produce curves intermediate to the ones for 100% and 50%.

TWO ELEMENT WATTMETERS

The measurement of polyphase power is somewhat more difficult than the measurement of single phase power. In the following discussion polyphase power is referred to as total power delivered to a given polyphase load by all 3, 4 or more number of lines used to feed the load. Inasmuch as the voltages and currents transmitted by the various lines could have widely varying phase characteristics, a standard definition of the power involved should be in agreement with, for instance, a calorimetric measurement of this power. The commonly accepted definition of polyphase power is that "if energy is supplied to a network through 'N' number of wires, the total power of the system is given by the algebraic sum of the readings of 'N' number of wattmeters so arranged that each one of the 'N' wires contains one current coil; the corresponding wattmeter potential coil is connected between that wire and some point common to all of the potential circuits."

This being a general definition, a further assumption can be made that this common point from which all potentials are measured can be upon one of the 'N' number of wires. This means that the potential between the common point and this wire is zero and that, therefore, one of the aforementioned 'N' number of wattmeters would read zero. Therefore, for any polyphase system of 'N' number of wires, the total power in the system can be read by 'N' minus 1 wattmeters. This is known as Blondell's Theorem.

Mathematical proof of this is as follows:

Let the supply conductors be denoted by the subscripts 1,2,3, . . . N; let the instantaneous voltages of the load be denoted by $V_1, V_2, V_3, \ldots V_N$ and the instantaneous currents at these same points be $1_1, 1_2, 1_3, \ldots 1_N$.

The current through wire $_1$ is then I_1 and the instantaneous power delivered through conductor $_1$ is I_1, V_1, and similarly for all the other conductors. Therefore:

$$P = I_1 V_1 + I_2 V_2 + I_3 V_3, \ldots I_N V_N \qquad (1)$$

Now let V_0 be the potential of any designated point on the system.

According to Kirchoff's Law:

$$I_1 + I_2 + I_3 + \ldots I_N = 0 \qquad (2)$$

Hence:

$$I_1 V_0 + I_2 V_0 + I_3 V_0 + \ldots I_N V_0 = 0 \qquad (3)$$

Subtracting (3) from (1):

$$P = I_1 (V_1 - V_0) + I_2 (V_2 - V_0) \ldots + I_N (V_N - V_0)$$

From this the average power will be:

$$P = \frac{1}{T}\int_0^T I_1 (V_1 - V_0)\, dt + \frac{1}{T}\int_0^T I_2 (V_2 - V_0)\, dt \ldots + \frac{1}{T}\int_0^T I_N (V_N - V_0)\, dt \qquad (4)$$

However:

$\frac{1}{T}\int_0^T I_1 (V_1 - V_0)\, dt$ is the reading of wattmeter

in conductor $_1$ and similarly for the other terms of the expression and (4) is the summation of the $_N$ wattmeter readings.

If now the common potential V is taken to be on one of the $_N$ wires then one of the power quantities in parenthesis will be zero, the corresponding wattmeter reads zero and 'N' minus 1 wattmeters are required.

The commonest commercial polyphase power with which one generally has to work is 3 phase. Having shown by Blondell's Theorem that the power in any polyphase circuit can be measured with N-1 number of wattmeters, it follows that in a 3 phase 3 wire circuit, the power can then be measured by 2 wattmeters.

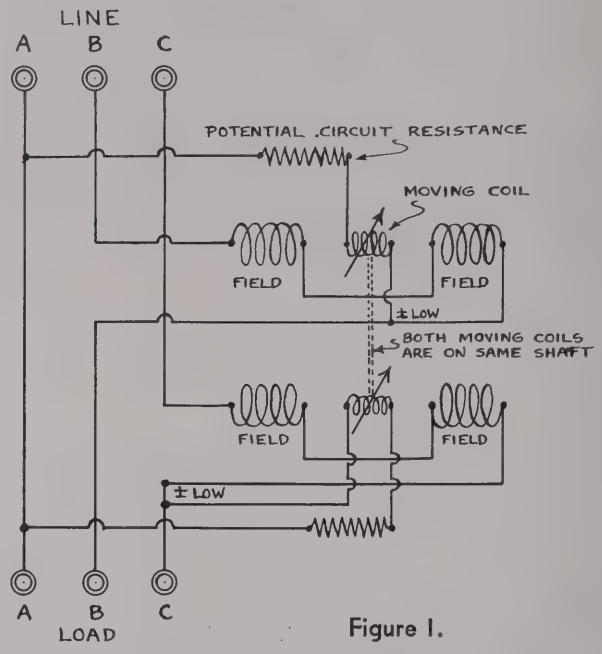


Figure 1.

Figure 1 shows the connection diagram for 2 wattmeters to measure the total power in the load fed by the 3 phase line A.B.C. The sum of the readings of the 2 wattmeters is equal to the total power being delivered to this load. As most loads are either balanced or nearly balanced, the 2 wattmeters used are most likely to be on the same range. If the moving coils of the wattmeters are mounted on a single shaft, their torques add mechanically and a single scale can be calibrated to give a direct addition of the quantity being measured by each instrument. This is shown by the dotted line in Figure 1, which represents a mechanical coupling between the moving coils of the 2 instruments. This assembly is commonly called a 3 phase wattmeter, but is somewhat more properly called a 2 element wattmeter, because it has many uses besides that of merely the measurement of 3 phase power.

The actual mechanical production of a 3 phase wattmeter demands mechanical skills of the highest order, because it is necessary to have 2 instruments whose characteristics are so identical that they can use a common scale throughout their entire range. To do this, the two moving coils must be very accurately aligned on a common shaft. Overall construction is complicated by the requirement that neither instrument have the slightest reaction upon the other movement, even though they are physically located adjacent to each other on a common shaft. The SENSITIVE RESEARCH 3 Phase Wattmeter is designed to meet these rigid requirements.

The 3 phase or 2 element wattmeter has other usages besides that of simply the measurement of 3 phase power. It can be applied in single phase work where 3 wire lines are used and the load may not be completely balanced. Figure 2 shows how the instrument indicates correctly the entire load on the line regardless of whether it is on one of the low voltage circuits or is bridged across the 2 outside or high voltage pairs.

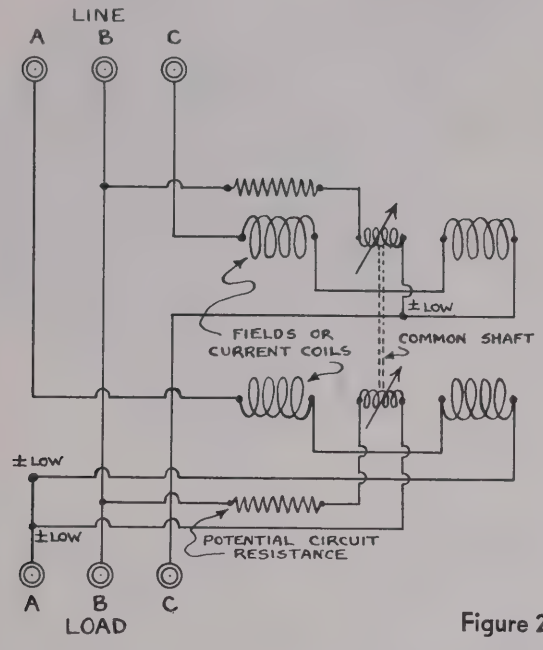


Figure 2.

The 2 element wattmeter can also be used where the sum of the power in any 2 lines is required, such as 2 single phase lines. The two portions of the movement are completely isolated and can be used in entirely different circuits, in which case the instrument measures the sum of the power being consumed in the 2 circuits. In addition, it can be used as a simple single phase wattmeter by either one of two methods. A single half of the movement can serve as a single phase wattmeter, and the scale reads directly the correct power in the circuit. If, however, the two current sections of the wattmeter are connected in series and the 2 potential coils are connected in parallel, the scale readings have to be divided by 2 to arrive at an actual single phase watt reading.

When the voltages and currents of each of the 3 phases are identical, the load is said to be balanced. Under this condition there are several methods by which the entire load power can be measured with a single phase wattmeter, by employing current transformers or a "Y" box. The simplest and most acceptable of these is the use of the "Y" box as shown in Figure 3. A "Y" box can be furnished with any standard wattmeter. It consists of a pair of resistors accurately matched to each other and to the total resistance of the potential circuit in the wattmeter with which it is to be used. The two resistors have their extremes attached to 2 of the 3 wires feeding the load. The center tap is connected to the normal potential circuit of the instrument with the low side grounded on the third leg (which also contains the current circuit of the wattmeter). Under these conditions the wattmeter reading, multiplied by 3, is identical to the total load in the 3 phase circuit.

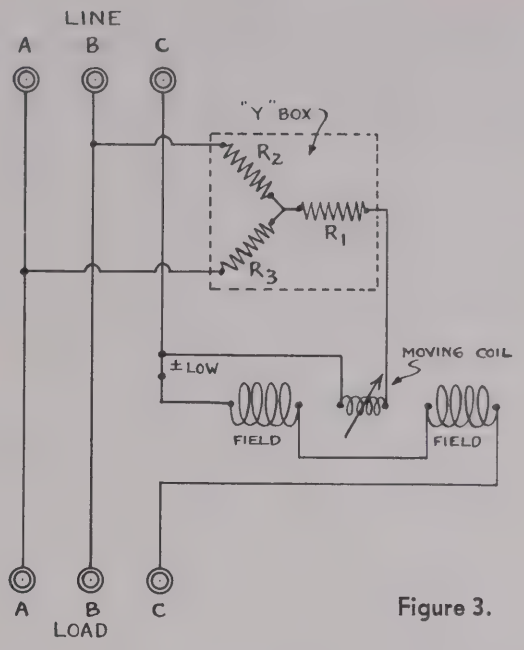


Figure 3.

A specialized use of the 2 element, 3 phase wattmeter is the measurement of the total power in a 4 wire, 3 phase circuit. The connections to accomplish this type of measurement are shown in Figure 4. From Blondell's Theorem, it would seem necessary to have 3 wattmeters for the measurement of total power in 4 wire, 3 phase lines. If all possible combinations of unbalanced lines were to be considered, this would, of necessity, be true. However, pre-supposing that the voltages only for the 3 phases will be balanced, and this is a condition which is normally encountered in practice, a reasonable measurement can ordinarily be made as diagramed in Figure 4. The connections shown allow for unbalanced current but are in error if the voltages are seriously unbalanced. This ordinarily occurs only at the end of very long 3 phase lines or where the power supply is rather inadequate. These are conditions which are not too frequently encountered and usage of the instrument in this fashion is very widespread.

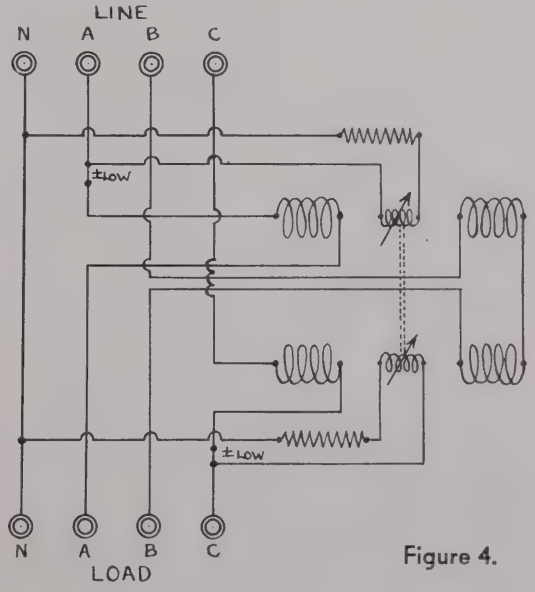


Figure 4.

MODEL PDW
POLYPHASE WATTMETERS

SPECIFICATIONS
AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
POWER FACTOR	50% to 100%
FREQUENCY	DC and 25 to 800 cps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 9" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	11 lbs. net; 20 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

OPTIONAL SPECIFICATIONS

1. Voltage ranges can be increased to 110, 220 and 440 v at no extra charge. Watt ranges remain the same but normal and maximum current ratings decrease in direct proportion. Specify by adding the letter "S" to the code word of the instrument ordered and state the potential ranges required. A wattmeter with two volt ranges can be increased to 110/220 v or 220/440 v. (Specify.)

2. Wattmeters with special ranges and/or scales can be supplied on special order in certain instances. Wattmeters can be compensated for frequencies above 800 cps and down to 15 cps. A detailed description of how to order special wattmeters is given on pages 302-303. Correspondence is required when ordering special instruments.

OPTIONAL ACCESSORIES

1. Voltage ranges can be increased by the addition of external multipliers. Correspondence required. Current ranges can be increased by the use of transformers. The Model TR Type 2 Transformer, with a 5 amp secondary, is recommended for use with wattmeters. Instrument accessories such as multipliers and transformers are described in Section 10.

2. Compensating inductors are available for the third leg of 3 phase circuits in those applications where the insertion of a measuring instrument appreciably unbalances the load voltages. The resistance and inductance of an inductor is matched to the field circuit of the wattmeter with which it is to be operated, and its use is restricted to that instrument. The serial number of the wattmeter must be furnished if compensating inductors are ordered separately. Both units should be purchased together. Price: $128.00.

MODEL PDW

GENERAL DESCRIPTION

The Model PDW is a 2 element AC/DC wattmeter for the measurement of single and 3 phase power down to 50% PF and up to 800 cps. It can be used in 3 phase 3 wire circuits, single phase 3 wire circuits and 3 phase 4 wire circuits. It indicates 3 phase power for any combination of balanced or unbalanced loads. All 2 element wattmeters are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element. Portable cases, made of tough, durable formica, are gasketed to provide an effective dust and humidity barrier.

Note: A discussion of 3 phase wattmeters and their application in 3 and 4 wire circuits is included on pages 310-311. It is essential reading as a guide in the ordering of wattmeters.

PANEL MOUNTED INSTRUMENTS

The Model PDW is also available for vertical panel mounting in an edgewise panel case with a 5" scale length. For dimensions, see page 316. Performance is the same as listed for the portable.

Specify: Model PDWEW-5 and code word of portable instrument having ranges desired.

Price: Add $50.00 to price of code word selected.

RANGES

Note: *Watt ranges are calculated by cross multiplying potential ranges and normal current ranges and multiplying by 2. To assist the reader, the instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGE			FIELD CURRENT PER PHASE (AMPS) Normal I (Unity PF)		Max. I (50% PF)		Approx. 60 cps	Potential Circuit	Scale		
100 Volts	200 Volts		Series	Parallel	Series	Parallel	va	Approx. Ω/v	Div.	Code	Price
15/30	30/60		.075	.15	.15	.3	.4	160	150/120	PDWAMIS	$600.00
25/50	50/100		.125	.25	.25	.5	.3	150	125/100	PDWANOT	600.00
37.5/75	75/150		.1875	.375	.375	.75	.3	170	150	PDWYFAT	600.00
75/150	150/300		.375	.75	.75	1.5	.4	160	150	PDWASUL	600.00
125/250	250/500		.625	1.25	1.25	2.5	.4	160	125/100	PDWARAB	600.00
150/300	300/600		.75	1.5	1.5	3.0	.35	160	150/120	PDWHACK	615.00
250/500	500/1000		1.25	2.5	2.5	5.0	.4	170	125/100	PDWASED	620.00
300/600	600/1200		1.5	3.0	3.0	6.0	.3	130	150/120	PDWAHLN	620.00
500/1000	1000/2000		2.5	5.0	5.0	10.0	.3	150	100	PDWARAC	645.00
50 Volts	**100 Volts**	**200 Volts**									
15/30	30/60	60/120	.15	.3	.3	.6	.6	200	150/120	PDWEAPA	$620.00
25/50	50/100	100/200	.25	.5	.5	1.0	.4	150	125/100	PDWEALM	620.00
50/100	100/200	200/400	.5	1.0	1.0	2.0	.4	160	100/80	PDWEAZO	620.00
75/150	150/300	300/600	.75	1.5	1.5	3.0	.3	160	150/120	PDWEAEN	635.00
125/250	250/500	500/1000	1.25	2.5	2.5	5.0	.4	170	125/100	PDWEAFE	640.00
250/500	500/1000	1000/2000	2.5	5.0	5.0	10.0	.3	150	125/100	PDWEAGZ	640.00

LOW POWER FACTOR POLYPHASE WATTMETERS

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.75% of full scale
POWER FACTOR	20% to 100%
FREQUENCY	DC and 25 to 500 cps
TYPE	Electrodynamometer
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Binding posts
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 9" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	11 lbs. net; 20 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings. **Potential circuits can be operated at 60% overload.**

OPTIONAL SPECIFICATIONS

1. Voltage ranges can be increased to 110, 220 and 440 v at no extra charge. Watt ranges remain the same but normal and maximum current ratings decrease in direct proportion. Specify by adding the letter "S" to the code word of the instrument ordered and state the potential ranges required. A wattmeter with two volt ranges can be increased to 110/220 v or 220/440 v. (Specify.)

2. Wattmeters with special ranges and/or scales can be supplied on special order in certain instances. Wattmeters can be compensated for frequencies above 500 cps and down to 15 cps. A detailed description of how to order special wattmeters is given on pages 302-303. Correspondence is required when ordering special instruments.

GENERAL DESCRIPTION

The Model PDLW is a 2 element AC/DC wattmeter for the measurement of single and 3 phase power down to 20% PF and up to 500 cps. It can be used in 3 phase 3 wire circuits, single phase 3 wire circuits and 3 phase, 4 wire circuits. It indicates 3 phase power for any combination of balanced or unbalanced loads. (See page 311.)

All 2 element wattmeters are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element. Portable cases, made of tough, durable formica, are gasketed to provide an effective dust and humidity barrier.

Note: A discussion of 3 phase wattmeters and their application in 3 and 4 wire circuits is included on pages 310-311. It is essential reading as a guide in the ordering of wattmeters.

OPTIONAL ACCESSORIES

1. Voltage ranges can be increased by the addition of external multipliers. Correspondence required. Current ranges can be increased by the use of transformers. The Model TR Type 2 Transformer with a 5 amp secondary is recommended for use with wattmeters. Instrument accessories such as multipliers and transformers are described in Section 10.

2. Compensating inductors are available for the third leg of 3 phase circuits in those applications where the insertion of a measuring instrument appreciably unbalances the load voltages. The resistance and inductance of an inductor is matched to the field circuit of the wattmeter with which it is to be operated, and its use is restricted to that instrument. The serial number of the wattmeter must be furnished if compensating inductors are ordered separately. Both units should be purchased together. Price: $128.00.

PANEL MOUNTED INSTRUMENTS

The Model PDLW is also available for vertical panel mounting in an edgewise panel case with a 5" scale length. For dimensions see page 316.

Performance characteristics are the same as listed for the portable type.

Specify: Model PDLWEW-5 and code word of portable instrument having ranges desired.

Price: Add $50.00 to price of code word selected.

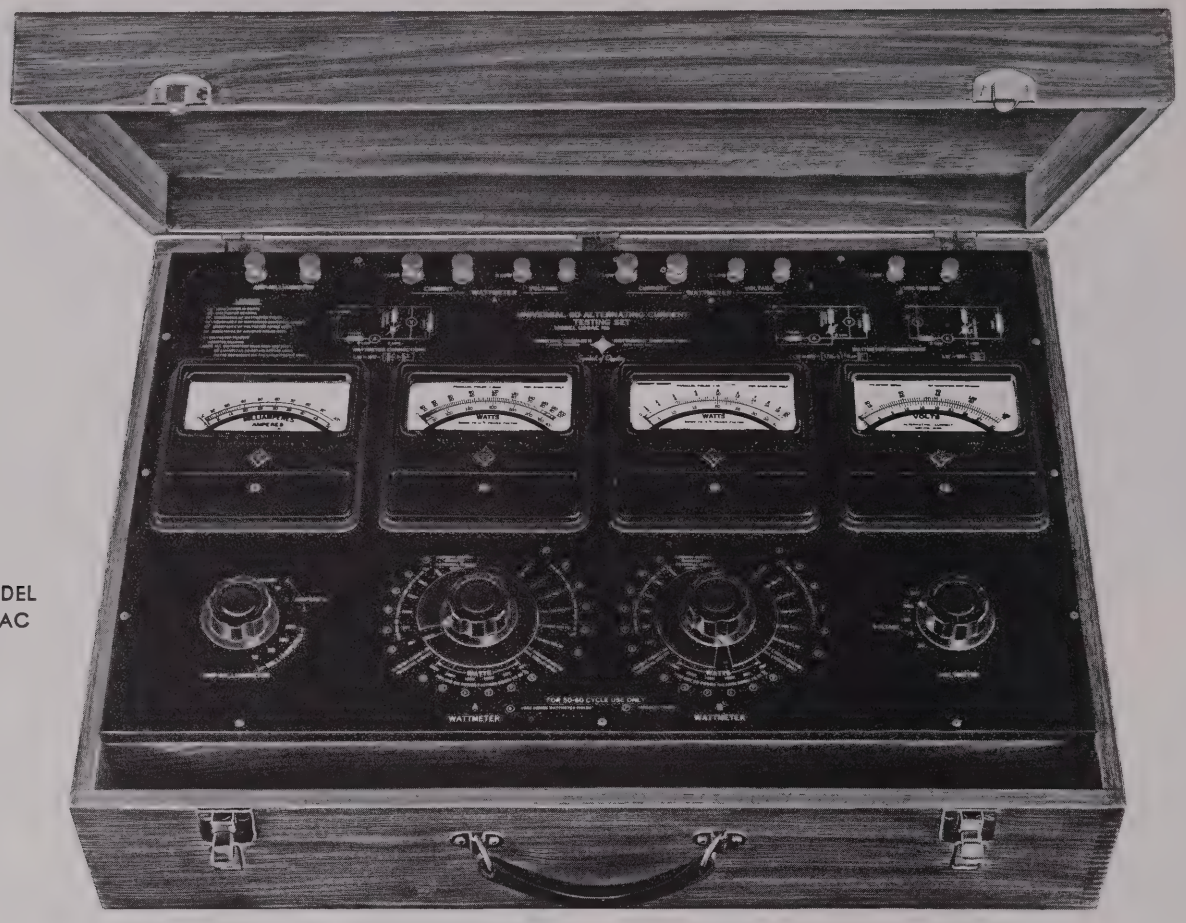
RANGES

Note: *Watt ranges are calculated by cross multiplying potential ranges and normal current ranges and multiplying by 2. To assist the reader, the instruments below have their watt ranges listed in separate columns headed by the potential ranges which provide them.*

WATT RANGE			FIELD CURRENT PER PHASE (AMPS) Normal I (Unity PF)		Max. I (20% PF)		Approx. 60 cps	Potential Circuit	Scale		
75 Volts	150 Volts		Series	Parallel	Series	Parallel	va	Approx. Ω/v	Div.	Code	Price
1.5/3	3/6		.01	.02	.05	.1	1	150	75/60	PDLWAMOS	$720.00
5/10	10/20		.033	.066	.166	.33	1.2	150	100	PDLWAKOR	680.00
7.5/15	15/30		.05	.1	.25	.5	1.2	150	75/60	PDLWACOT	680.00
10/20	20/40		.066	.133	.333	.666	1.2	160	100/80	PDLWAROT	680.00
15/30	30/60		.1	.2	.5	1.	1.1	150	75/60	PDLWACUM	680.00
20/40	40/80		.133	.266	.66	1.33	.6	120	100/80	PDLWAPOT	680.00
37.5/75	75/150		.25	.5	1.25	2.5	.9	150	75	PDLWAKER	690.00
75/150	150/300		.5	1.0	2.5	5.	1.5	160	75/60	PDLWAKIT	700.00
150/300	300/600		1.	2.	5.	10.	1	150	75/60	PDLWARUS	715.00
300/600	600/1200		2.	4.	10.	20.	1.3	170	60	PDLWAAST	740.00
375/750	750/1500		2.5	5.0	12.5	25.	.9	120	75	PDLWAKOD	765.00
75 Volts	**150 Volts**	**300 Volts**									
1.5/3	3/6	6/12	.01	.02	.05	.1	1	150	75/60	PDLWATOS	$740.00
5/10	10/20	20/40	.033	.066	.166	.333	1.2	150	100/80	PDLWATUF	700.00
15/30	30/60	60/120	.1	.2	.5	1.	1.1	150	75/60	PDLWATYI	700.00
20/40	40/80	80/160	.133	.266	.666	1.33	.6	120	100/80	PDLWATKO	700.00
37.5/75	75/150	150/300	.25	.5	1.25	2.5	.9	150	75/60	PDLWATSA	710.00
75/150	150/300	300/600	.5	1.	2.5	5.	1.5	160	75/60	PDLWATTI	720.00
150/300	300/600	600/1.2 kw	1.	2.	5.	10.	1	150	75/60	PDLWATBA	735.00
300/600	600/1200	1.2/2.4 kw	2.	4.	10.	20.	1.3	170	60/120	PDLWATFO	760.00
375/750	750/1500	1.5/3 kw	2.5	5.	12.5	25.	.9	120	75/60	PDLWATRI	790.00

UNIVERSAL AC TEST SETS

MODELS U60AC, U400AC and U1000AC



MODEL U60AC

The Models U60AC, U400AC and U1000AC are portable test sets that combine separate indicating instruments to measure wattage, voltage and current directly and enable power factor and phase angle to be easily calculated. The test sets are identical except as regards variations in the design of indicating instruments to achieve greater accuracy over a wider frequency span. The Models U60AC and U400AC for use at 50-60 cps and 50-400 cps, respectively, contain two 18 range, single phase, electrodynamometer AC/DC wattmeters, a 4 range moving iron AC voltmeter and a 7 range transformer-coupled moving iron AC milliammeter-ammeter. The Model U1000AC, for use on DC and 50-1000 cps, substitutes AC/DC thermocouple instruments with automatic thermocouple overload protection for the moving iron designs. All instruments have true rms response.

The basic electrical indicating instruments are housed in University Model style cases and the wattmeters conform to the performance specifications listed on pages 306-307. The voltmeters and ammeters made for use up to 400 cps have the same general characteristics as the Model NSI described in Section 4, excepting they have a 4″ scale length.

The 1000 cps test set incorporates a thermocouple voltmeter and an ammeter similar to the University Model described in Section 7 excepting they have automatic overload protection and temperature compensation between 20° and 30°C. The protection system safeguards thermocouples against overloads of 500% or twice the highest instrument range, whichever is the lesser figure. Semiconductor techniques are employed to automatically shunt the current around a thermocouple if currents exceed normal full scale values. It preserves the full advantages of thermal type instruments, e.g., true rms response, high frequency operation, and high sensitivity. However, in square loop magnetic material testing or in noise measurements, if sharply peaked waves are imposed, the instrument will begin clipping the top of the spikes at approximately a peak to rms ratio of 4 to 1. Hence waves with greater than this peak to rms ratio will tend to read low. In the event the application makes it desirable, the operator may easily disconnect the protection system from the measuring circuit.

Each of the instruments is provided with separate input terminals enabling simultaneous measurement of all parameters. The total power in polyphase circuits may be measured by the two wattmeter method in the region where the ranges of the two wattmeters overlap. "Y" boxes can be supplied at an additional cost of $75.00 for the measurement of balanced 3 phase loads. The use of "Y" boxes is restricted to the wattmeter with which they are to be used and they should be ordered at the same time. Additional current ranges can be obtained by using external transformers. The Model TR Type 2, with a 5 amp secondary, is recommended for use with wattmeters. (See Section 10.)

UNIVERSAL TEST SETS

Operation of the test sets is simplified by providing all switch controlled ranges. Indicating instruments have diamond pivots and spring mounted sapphire jewels. The oak wood case has a hinged cover and a durable carrying handle. Size is 25" x 18¼" x 8 13/16" deep. Approximate weight is 50 lbs. net, 140 lbs. shipping.

MODEL U60AC — Frequency 50-60 cps

Voltmeter
Accuracy: .5% of full scale

Range:	30	75	150	300 v
Approx. Resist.:	315	1575	3150	6300 Ω

Scale: 60/75 divisions printed 0-30 and 0-75/150

Ammeter
Accuracy: .5% of full scale

Range:	.01	.05	.1	.5	1	5	10 amps

Approx. Burden: 1 va at 60 cps
Scale 100 divisions printed 0-50/100

Code UTSET **Price $995.00**

Wattmeter "A"
Accuracy: See below*
Scale: 80/100 divisions printed 0-400 and 0-50/100/200

Watt Ranges	Volt Ranges	PF	
50	50	10%	50-60 cps use only
100	50	10%	
100	100	10%	
200	100	10%	
200	200	10%	
400	200	10%	
100	50	20%	50-400 cps use except 50v 50-125 cps
200	50	20%	
200	100	20%	
400	100	20%	
400	200	20%	
800	200	20%	
250	50	50%	50-1000 cps use except 50v 50-125 cps
500	50	50%	
500	100	50%	
1000	100	50%	
1000	200	50%	
2000	200	50%	

Wattmeter "B"
Accuracy: See below*
Scale: 80/100 divisions printed 0-40 and 0-5/10/20

Watt Ranges	Volt Ranges	PF	
5	50	10%	50-60 cps use only
10	50	10%	
10	100	10%	
20	100	10%	
20	200	10%	
40	200	10%	
10	50	20%	50-400 cps use except 50v 50-125 cps
20	50	20%	
20	100	20%	
40	100	20%	
40	200	20%	
80	200	20%	
25	50	50%	50-1000 cps use except 50v 50-125 cps
50	50	50%	
50	100	50%	
100	100	50%	
100	200	50%	
200	200	50%	

MODEL U400AC
Frequency DC and 50-400 cps

Specifications same as for U60AC excepting for frequency range, and voltmeter and ammeter accuracy .75%.

Code UTSAM **Price $1050.00**

MODEL U1000AC — Frequency DC and 50-1000 cps

Specifications same as for U60AC excepting for frequency range, deviations noted in general description, and (1) voltmeter sensitivity 100 Ω/v and accuracy .75%, (2) ammeter range resistances approximately 15/10/5.5/1.2/.6/.12/.06 Ω and accuracy .75%.

Code UTSUR **Price $1185.00**

*WATTMETER ACCURACY

The identical wattmeter is included in the Models U60AC, U400AC and U1000AC.
Accuracy varies in operation according to voltage range, frequency and power factor as follows:

(1) .5% at (a) DC and 50-400 cps at 50% PF and higher; (b) DC and 50-125 cps at 20% PF, when usage is on 100/200 v ranges; (c) DC and 50-70 cps at 20% PF when usage is on 50 v range.

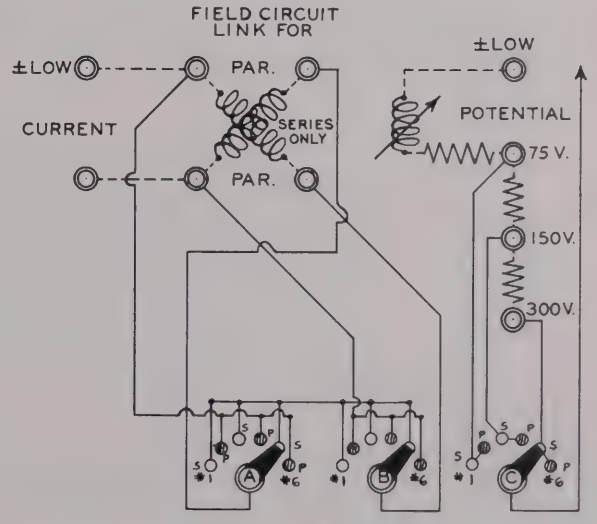
(2) 1% at DC and 50 to 400 cps for 20% PF.
(3) 2% at 60 cps for 10% PF.
(4) .75% at DC and 50 to 1000 cps at 50% and higher power factor on 100/200 v ranges.

SWITCH CONTROLLING OF SINGLE PHASE WATTMETERS

Edgewise panel mounted single phase wattmeters are normally furnished with binding posts on the rear of the case. Since it may be desirable to change watt ranges by switching externally from the front of the panel, such a circuit and its explanation is shown in Fig. 1. Note that the rating of the switch used in the series-parallel field circuit should take into consideration maximum values of current. It should have extremely low contact resistance.

O denotes series fields; • parallel fields. Switches A, B and C are triple ganged. Assume ranges of 75/150/300/600 watts; 75/150/300 volts; normal current at unity PF of 1 & 2 amps. Switching positions 1 through 6 would give range values as follows:

Switch Position	Volt Range	Normal Current Amps	Watt Range
1	75	1	75
2	75	2	150
3	150	1	150
4	150	2	300
5	300	1	300
6	300	2	600



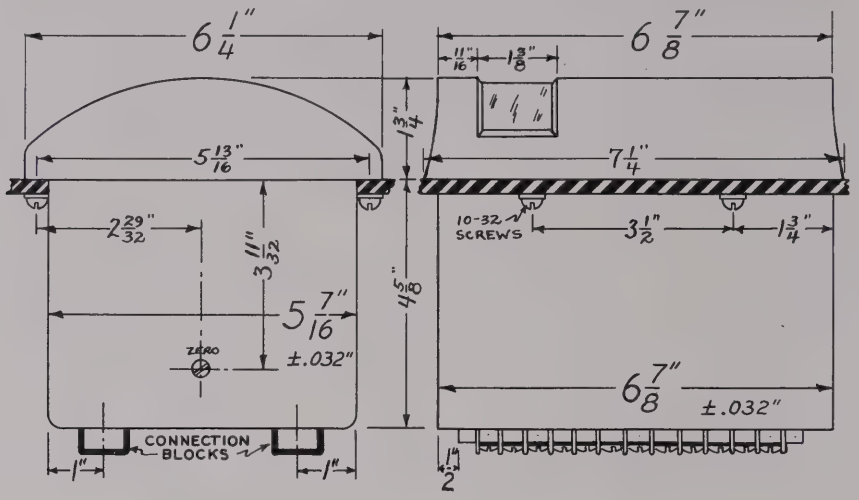
External Switching Circuit for Single Phase Wattmeter

MOUNTING DIMENSIONS FOR EDGEWISE PANEL INSTRUMENTS

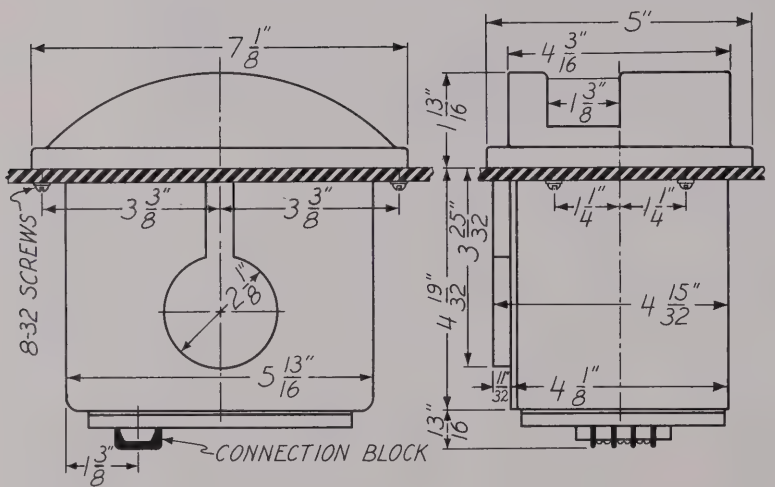
Edgewise panel cases are supplied for flush mounting in a vertical panel. Binding posts or connection lugs are furnished in the rear. Cases are of die cast aluminum with a black wrinkle finish. Switches, when supplied, are as indicated in the drawings. (See individual portable model specifications.) External zero shifters are supplied on the front of EW-5A and EW-7A cases.

NOTE

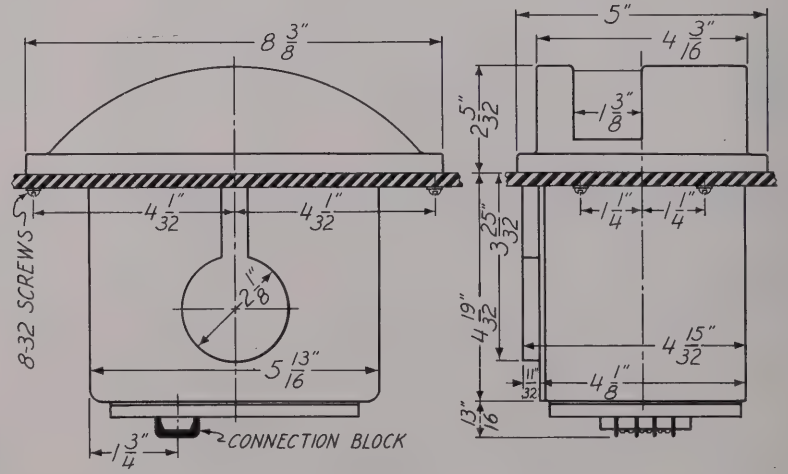
The Types EW-5A and EW-7A replaced the Types EW-5 and EW-7 in May, 1961. There are minor dimensional differences between the two types. For purposes of exact replacement, the Types EW-5 or EW-7 can be supplied at no extra charge, *but must be specified at time of ordering.*



PDWEW-5 and PDLWEW-5 CASE, Scale Length 5"
for Models PDW and PDLW



Type EW-5A DEEP CASE, Scale Length 5"
for Models DW and DLW



Type EW-7A DEEP CASE, Scale Length 7"
for Models DW, DLW, PF and PPF

Prices and Specifications Subject to Change Without Notice.
Printed in U.S.A. 75-1

AC-DC ELECTROSTATIC VOLTMETERS

FOR

R.M.S. & PEAK VOLTAGE MEASUREMENTS

S. STERLING CO.
Manufacturers' Representatives
3300 SOUTH DIXIE DR.
DAYTON 39, OHIO
AX 8-7573

MODELS

ESH ESD

VPA

UNIVERSITY

CRV

FROM 120 VOLTS TO 100,000 VOLTS

IN

SINGLE AND MULTIRANGE DESIGNS

PEAK VOLTAGE UNITS

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, NEW YORK.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

MODERN ELECTROSTATIC VOLTMETERS

The SENSITIVE RESEARCH ELECTROSTATIC VOLTMETER is a modern, dependable voltage measuring instrument which has evolved from the discoveries of static electricity by the ancient Greeks.

There is an interesting historical background to the subject of static electricity and electrostatic measuring instruments.

History tells us that the ancient Greeks were acquainted with the phenomena of what we call today "electric forces." "THALES OF MILETUS" knew that amber, when rubbed would attract to itself all sorts of light particles. The modern word "electricity" comes from the Greek word "electron", their name for amber.

In the early part of the twentieth century, SENSITIVE RESEARCH designed and built the first models of its complete line of electrostatic instruments, and has now grown to be the largest manufacturer of electrostatic instruments in the world today. At that time the modern super insulating plastics had not been developed and in order to obtain the very high resistance which is so **NECESSARY** in electrostatic voltmeters, we had to utilize the very material with which the Greeks had discovered electricity—ELEKTRON or AMBER as we know it. The electrostatic voltmeters built with amber insulation in the early 1930's are comparable in insulation with the present polystyrene insulated models.

The first consideration in understanding these instruments is the fundamental one, that they are VOLTAGE OPERATED. This distinguishes them from ALL other types which are CURRENT OPERATED. In some cases they do draw current, sometimes even an appreciable amount, but it is incidental to the operation and is NOT the cause of the deflection. Their deflection is directly proportional to the RMS value of the voltage appearing between the plates—and to nothing else.

On D.C., the instrument draws a momentary charging current which almost instantly drops to a negligible value determined by the insulation resistance of the instrument. The insulation resistance is always several megamegohms which varies with the individual instrument, temperature, humidity and other factors. However, under the WORST conditions, current from this cause is several hundreds of times smaller than the current of any other type of voltmeter. The charging current is almost always a negligible quantity, its exact value of course being determined mainly by the inductance and resistance of the external circuit. This means it is safe to say that in the great majority of steady D.C. circuits, the Electrostatic voltmeter can be considered a "ZERO CURRENT" device.

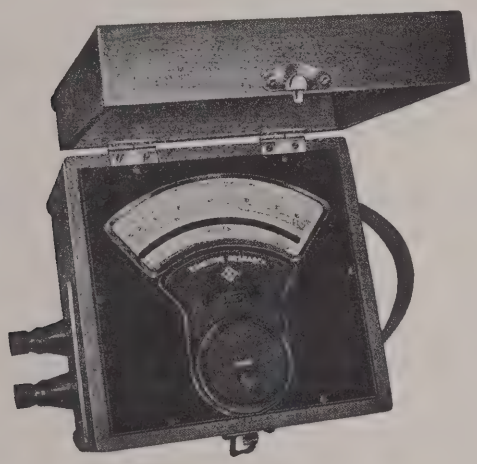
It should be understood by the user of the electrostatic voltmeter that the instrument measures RMS VOLTAGE. This is true whether the voltage is D.C., sinusoidal A.C., or of the pulse type. The pulse or high peaked type of voltage wave usually has an RMS value which is small compared to the peak value. This sometimes misleads the user into thinking that the instrument is not functioning properly. Sometimes, as in a typical radar measurement, the ratio of peak to RMS may be as much as one thousand to one. In applications such as radar pulse measurement, ignition voltage measurement, or any peaked or pulse measurement, we recommend the use of a Peak Voltage Unit (Model VPA as described on page 356), or a crest voltmeter unit (Model CRV as described on page 362).

The frequency range of the electrostatic voltmeter is almost unlimited. There are two phenomena which place the upper limit on the use of the electrostatic voltmeter. The first is the effect of loading on the circuit being measured. The voltmeter as a circuit element is a very low loss capacitor. Its capacitance lies between the limits of 225 mmf. for the 120 volt instruments to about 10 mmf. for the 100 kv. In the radio frequency range the reactance of the instrument is a quantity to be considered. The second limitation is that of the instrument and its leads behaving like a resonant or partially resonant transmission line. The leads and the capacitive termination formed by the voltmeter movement may result in a voltage distribution along the line which is not constant. Thus the instrument may indicate a voltage which is not the same as that to which the leads are connected.

Let us see what can be measured with our electrostatic voltmeters. From Coulomb's law, and more analysis, we know that the instantaneous torque developed by the electrostatic voltmeter, is equal to a constant (for a given deflection) times the square of the instantaneous terminal voltage. If the instantaneous terminal voltage is steady D.C., then the average torque, which produces the deflection, is the same as the instantaneous torque and the instrument reads D.C. voltage. In addition to the instrument reading D.C. voltage, let us examine what happens when alternating voltages are applied to the electrostatic voltmeter. As stated above, the instantaneous torque of the electrostatic voltmeter is proportional to the square of the instantaneous terminal voltage. This results in the alternating voltage producing surges of torque which are mechanically averaged by the instrument movement. The instrument movement can do an accurate averaging job because

it has a mechanical time constant which is very long, compared to the period of the alternating voltage being measured. Consequently, the instrument responds to the theoretical concept of root mean square voltage, regardless of wave shape.

Since the electrostatic voltmeter as a circuit element is a high quality capacitor, the power taken by the instrument is negligible. Of course, in exchange for this extremely high power sensitivity, the electrostatic voltmeter requires that the necessary charge be supplied from the circuit under measurement, whether the measurement is alternating current or direct current. On direct current, only the initial charging current is required, whereas on alternating current, a capacitive alternating current flows just as in any capacitor. The capacitive current is negligibly small at power or audio frequencies, and there are many electrostatic voltmeters in use even at radio frequencies.



A MODERN
PORTABLE ELECTROSTATIC VOLTMETER

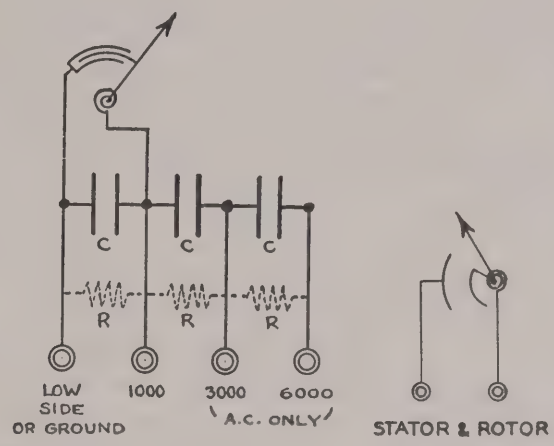
MODEL ESD

Accuracy 1% Scale Length 5"
(Insulation Resistance 1 x 10^{15} ohms)

Electrostatic instruments have an inherent limitation in frequency based on the current carrying capacity of the instrument. For any given combination of voltage and frequency the capacity of the instrument will allow a current to flow. This current must not exceed 200 ma. (for all models) or a permanent change in calibration may occur. This gives an upper frequency limit which is dependent on the voltage at which the instrument is used.

For example: A 30 kv. instrument (capacity about 10 mmf.) used at 20 kv. could be used up to approximately 160 kc.

The question naturally arises as to how we can obtain multirange electrostatic voltmeters. Since sensitivity of an electrostatic voltmeter depends upon the spacing of the electrodes, we can vary the sensitivity by varying the electrode spacing. The SENSITIVE RESEARCH Model ESH high voltage electrostatic voltmeter uses this principle in a very refined mechanism for positioning the stationary electrode in as many as four positions to obtain up to four ranges of voltage measurement with one instrument. The ranges available are shown on page 357. It also has the advantage of the capacity of the voltmeter becoming **LOWER** as the voltage ranges are increased.



MULTIRANGE

The Model ESD and University Model electrostatic voltmeters obtain their multiranges by different means. It is not convenient to vary the spacing of the electrodes in the more sensitive instruments and so capacity type voltage multipliers are used. From the circuit shown above it will be seen that the condensers "C" will form a voltage divider for AC components which will provide accurately fixed multiplying factors. The resistances shown as "R" in dotted lines are the upsetting factor when DC is applied. These represent the leakage resistances of the individual condensers used in the divider. Due to normal manufacturing tolerances this leakage resistance can only be held ABOVE SOME GIVEN HIGH VALUE, but NOT TO A DEFINITE VALUE OF RESISTANCE. The DC path, of course, is through these various leakage resistances and the voltage appearing across the movement is proportional to these uncertain leakages and hence of a very variable value.

Because of the uncertainty of these leakages, multirange Model ESD and University Model instruments should be used for DC readings ONLY ON THE LOWEST RANGE.

SPECIAL USES FOR THE ELECTROSTATIC VOLTMETER

AS A HIGH IMPEDANCE AC VOLTMETER:

At commercial power frequencies, the electrostatic voltmeter provides a very high impedance instrument for many measurements.

For instance, the Model ESH, 30 Kilovolt instrument at 60 cycles will have an impedance of about 266 megohms due to its capacitance. It would draw a current of only 120 microamperes. It would be comparable with any type of electronic instrument in impedance, PLUS being MUCH superior for long term stability.

At lower voltages such as 1000 volts, 60 cycles, the Model ESD instrument with a capacitance of about 55 mmf. would draw a current of 20.6 microamperes. This represents an equivalent impedance of 48.5 megohms.

High voltage measurements on high reactance transformers such as are used for cathode ray tube supplies and low current high voltage supplies for breakdown testing are examples requiring high voltage measurements at low current drain.

It should also be noted that this is a completely reactive current and not power consumption even at these low levels. This is usually only a theoretical advantage however, rather than of practical importance.

The inclusion of an electrostatic instrument for A.C. measurements at power frequencies may in many cases eliminate the necessity of electronic circuitry with the attendant difficulties of tube replacements, recalibrations, etc.

AS AN EXTREMELY HIGH RESISTANCE DC METER:

The Electrostatic Voltmeter when used as a DC voltmeter has no equal in having high input resistance at high voltage. The electrometer tube voltmeter for low voltages of a few volts has a comparable input resistance, but when the range of 100 volts and up is reached, the electrostatic instrument is in a class by itself.

An electrostatic instrument on D.C. draws only a momentary charging current due to its capacitance and then will draw a very low current thereafter. The value of this current will be very small. For instance a 10,000 volt instrument will have a leakage resistance of at least 3×10^{15}. After the initial charging current such an instrument will draw a current of only $\frac{1}{30{,}000}$ th of a microampere, a completely negligible current.

This low current is of extreme value for many applications. Many applications such as Geiger counters, condenser microphones, ionization chambers, etc., use a polarizing voltage from a VERY limited current source. It is difficult to measure these voltages with ordinary instruments because of the current drain error. With the electrostatic instrument true readings are easily obtained. In fact, the current drain is so low that it can be neglected entirely and the meter left connected for monitoring during any operation.

The new so called "atomic" batteries using a radio active source for providing power in place of chemical action can be readily checked with an electrostatic voltmeter. Any other type instrument will give incorrect low readings because of the limited current capabilities of this type of battery.

Any requirement for measuring voltage in the DC ranges from 30 to 40 volts up to 100 kilovolts in which very limited power is available for operation of an instrument becomes the natural field of measurement for the electrostatic voltmeter.

OTHER USES

It is understood that at all times an electrostatic instrument reads the RMS value of the impressed voltage. This fact makes the instrument very useful as an AC-DC transfer standard, particularly in the high voltage ranges where its low power consumption makes it an attractive transfer device.

The practically infinite impedance of the instrument makes it a very successful tool for the investigation of Electrostatic fields. Such use in the printing, textile and paper industries is widespread. In a place where quantities of any insulating material is moved, there are static charges built up which can cause trouble. This is particularly true where long continuous sheets are handled, such static fields causing sticking, misfeeding, sparking and other difficulties. By providing satisfactory pick up by means of a probe or collector of appropriate type the electrostatic instrument will provide measurement of wide fields with an accuracy limited primarily by the pick up means rather than the instrument. The measurement and plotting of such fields is, of course, the first step in being able to eliminate them to the extent required for satisfactory performance of the equipment.

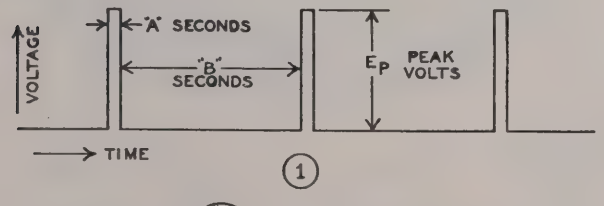
The general principal in setting up such a measurement system is to provide a well insulated conductor from the field to a "field free" position when it is connected to the high side of the Electrostatic Voltmeter and the low terminal grounded. Under these conditions the voltmeter reading will then be directly proportional to the field intercepted by the conductor. If such measurements have to be made at a distance, shielded cable can be used to eliminate pick up on the leads, however it must be of exceptionally high insulation value or it will provide an attenuation of reading too great to tolerate.

PEAK VOLTAGE MEASUREMENTS

The need for a peak reading electrostatic voltmeter has been growing for many years. During the 2nd world war we, as pioneers in the electrical measurements field, experimented with peak voltage measuring circuits using the components which were then available. In the ensuing years there has been an increasing need for an accurate, simple, direct method for making peak voltage measurements *without* loading the circuit being measured. "SENSITIVE RESEARCH" ELECTROSTATIC VOLTMETERS have, for over two decades, been the leading method for making both A.C. and D.C. high voltage measurements with virtually no power drawn from the circuit under measurement. These electrostatic voltmeters have provided very reliable service in the measurement of true RMS voltage. In recent years the need for peak voltmeters in radar, corona, ignition, and hipot measurements has become increasingly more pressing. To meet this need we have developed the "SENSITIVE RESEARCH" PEAK VOLTMETER UNITS. These units or accessories provide a very convenient means of converting most "SENSITIVE RESEARCH" electrostatic voltmeters to an accurate peak reading voltmeter which takes a negligible amount of power from the circuit under measurement.

Multirange ESD and University instruments used on other than the lowest range are not suitable for this use. All other instruments including multirange ESH types are satisfactory.

Probably the most difficult type of peak voltage measurement is that of narrow pulses such as are used in radar. Figure 1 shows a typical radar pulse and the peak voltmeter circuit is shown in figure 2.



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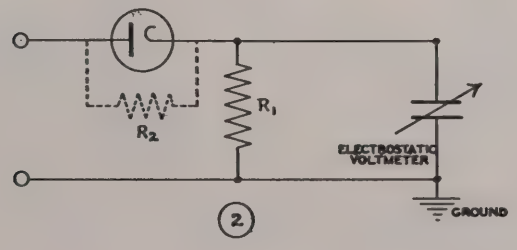
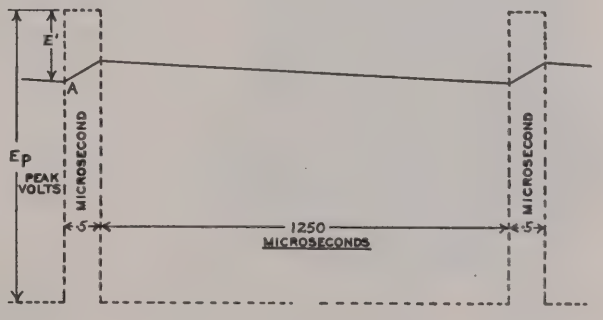


2

For the duration of the pulse ("A" microseconds) the diode is conducting and the forward resistance R_2 is low compared to the leakage resistance R_1. The charging rate of the voltmeter is determined by R_2, the forward resistance of the diode and the capacitance of the voltmeter. The charging time constant R_2C is about 5 microseconds for the low voltage peak unit used with a model ESD electrostatic voltmeter, and 10 microseconds for the high voltage peak unit used with a model ESH electrostatic voltmeter.

During the time "B" between pulses, the charge stored in the capacitance of the voltmeter leaks off through resistor R_1. Since the leakage resistance of the voltmeter is high compared to R_1, it is considered negligible. The leakage resistance of the meter is about 10^{15} ohms compared to 10^{10} for R_1 making R_1 the main source of leakage. The voltmeter and the resistance R_1 combine to give a discharging time constant of about 5 seconds.

Let us illustrate the operation of the peak voltmeter with an actual example. We have chosen a typical problem of 0.5 microsecond pulse width at 800 pulses per second. The steady state of repetitive charge and discharge is reached in a matter of a few seconds. If we examine the instantaneous voltage at the terminals of the electrostatic voltmeter, we will find that it varies with time as shown by the solid line in figure 3. Starting at the Point A, the diode starts conducting and current flows to charge the capacitance of the voltmeter.



3

If the discharging time constant is long compared to the charging time, as it is in this case, then the charging rate will be approximately $\frac{E'}{R_2C}$ volts per second or $\frac{100}{R_2C}$ percent per second. This is equivalent to $\frac{10^{-4}}{R_2C}$ percent per microsecond.

PEAK VOLTAGE MEASUREMENTS

For a time constant of 5 microseconds and a charging time of 0.5 microsecond, the rise in voltage across the voltmeter will be 10% of the voltage E'. During the discharging period the meter C starts to discharge toward zero volts. If it is assumed that the discharge starts from the actual peak voltage Ep, then for a discharging time constant of 5 seconds and a discharge time of 1250 microseconds, the drop in voltage across the meter is .025% of Ep. Since this is a steady state charge and discharge, we can then say that the rise in voltage during the pulse (10% of E') equals the reduction in voltage during the time between pulses (.025% of Ep), or: .1 x E' = .00025Ep or E' = .0025 Ep. This indicates that the lowest voltage (Ep—E') at the voltmeter terminals is only 0.25% lower than the actual peak voltage. If the pulse width increases or if the pulse repetition rate increases this error becomes smaller. Of course, each type of wave is a different problem but for almost any of the more common types the error introduced by the peak voltmeter unit will be less than 0.5%.

There are two important functions to be performed by the peak voltmeter. One is to rectify the voltage being measured, and the other is to store the peak value so that it may be read on an instrument scale. Now instead of requiring the electrostatic voltmeter to have a very long time constant, we must provide a discharge path for the voltmeter in order to permit the instrument to settle to a new reading in reasonable time in the event that the peak voltage being measured changes to a lower value. This leakage resistor is R_1 in Fig. 2.

The peak voltmeter stores positive peaks and during the negative swing of the voltage, the rectifier is subjected to the inverse peak voltage of the wave. In the case of the usual pulse voltages, the peak value is the same as the inverse peak, but for sinusoidal or repetitive symmetrical waves, the inverse peak voltage is twice the peak value. For this reason, SENSITIVE RESEARCH PEAK VOLTMETER UNITS are rated in inverse peak volts.

When properly connected to our electrostatic voltmeters the instrument reading will be the peak voltage of the particular circuit being measured.

These units are normally supplied for use on "positive" peaks but can be furnished for "negative" peaks. See ordering information below.

Mounted in Shielded Containers with Insulated Covers and ground binding post

For use on "POSITIVE" or "NEGATIVE" Peaks

MODEL VPA
LOW VOLTAGE PEAK UNIT

ELECTRICAL CHARACTERISTICS

Maximum Inverse Peak Voltage.....3000 Volts
Charging Time Constant.....5 microseconds
Discharging Time Constant.....5 seconds
Frequency Range .....60 cps to 1 mc

MECHANICAL DIMENSIONS
4" Dia. 5" High
Weight 4 pounds

	Code	Price
LOW Voltage Positive Peak Unit	LOPEEK	$175.00
LOW Voltage Negative Peak Unit	NEGLO	225.00

MODEL VPA
HIGH VOLTAGE PEAK UNIT

ELECTRICAL CHARACTERISTICS

Maximum Inverse Peak Voltage.....30,000 Volts
Charging Time Constant.....10 microseconds
Discharging Time Constant.....5 seconds
Frequency Range .....60 cps to 1 mc

MECHANICAL DIMENSIONS
6" Dia. 8" High
Weight 5 pounds

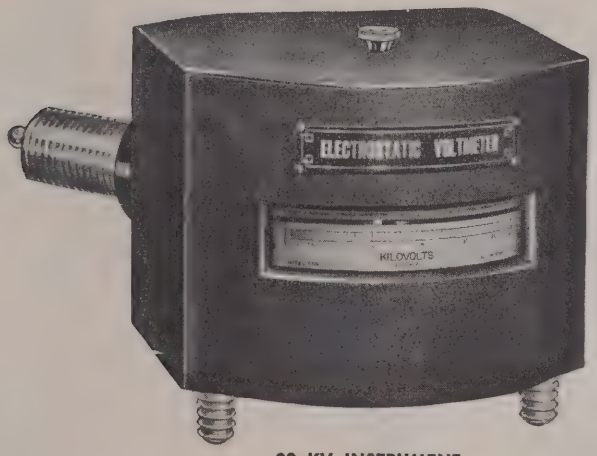
	Code	Price
HIGH Voltage Positive Peak Unit	HIPEAK	$245.00
HIGH Voltage Negative Peak Unit	NEGHI	295.00

Shipped complete with all necessary instructions

SPECIFICATIONS

HORIZONTAL USE ONLY

ACCURACY	1% (for .5% see pg. 358)
SCALE LENGTH	6 inches
SCALE DIVISIONS	Up to 100 as required
PERIOD	3 - 5 seconds
TYPE	Electrostatic
PIVOTS	Diamond
JEWELS	Sapphire Spring Mounted
CAPACITY	See below
SHIELDING	Electrostatic
CASE	Cast Aluminum
SIZE	Table on right
INST. WEIGHT	Table on right



30 KV INSTRUMENT

The insulation resistance of these instruments is very high—for instance on the 75 K.V. and 100 K.V. design it is more than 5 x 10^{15} ohms.

MODEL ESH

Double Pivoted Movement

SINGLE RANGE

Volts	Type Case	Lowest Reading	Code	Price
5000	A	1000	ESHAPE	$280.00
7500	A	1500	ESHOLM	280.00
10000	A	2000	ESHILT	295.00
15000	A	3000	ESHAIM	310.00
20000	A	4000	ESHUNS	330.00
25000	A	5000	ESHULK	345.00
30000	A	6000	ESHORE	375.00
40000	B	8000	ESHPOT	458.00
50000	B	10000	ESHIGH	525.00
60000	C	12000	ESHPEC	600.00
75000	C	15000	ESHHIY	800.00
*100000	D	20000	ESHOOP	1225.00

*Accuracy on DC 2%. (Supplied with front zero shifter.)

Type Case	Size	Weight	Shipping Weight
A	16" x 13" x 9"	20 lbs.	40 lbs.
B	23½" x 13" x 14½"	30 lbs.	90 lbs.
C	42½" x 21¼" x 22"	92 lbs.	160 lbs.
D	52" x 27" x 26"	135 lbs.	230 lbs.

HIGH VOLTAGE ELECTROSTATIC DESIGN MULTIRANGE VOLTMETERS FOR A.C. AND D.C.

By using a uniquely designed internal high voltage switch, multiranges of voltages from 5000 full scale volts up to 50,000 volts are obtained. This system has a distinct advantage because the capacity of the instrument decreases as the ranges increase. Briefly explained, the switch operating in successive "click" positions, moves the stator electrode AWAY from the rotor in predetermined positions. The voltmeter is not limited to AC but can be used over all its ranges on DC. The capacity of its lowest range (5000 volts) is approximately 30 mmfd, and is about 10 mmfd at 50 to 100 kilovolts.

Single, double and triple scale instruments are supplied with mirrors.

Four range instruments DO NOT have mirrors due to space limitations.

SWITCH CONTROLLED MULTIRANGE VOLTMETERS

Full Scale Values	Type Case	Lowest Reading	Code Word	Price
5000/10000	A	1000 Volts	ESHAKE	$330.00
5000/15000	A	1000 Volts	ESHEEP	340.00
10000/15000	A	2000 Volts	ESHICK	348.00
10000/20000	A	2000 Volts	ESHOTS	368.00
10000/30000	A	2000 Volts	ESHAMP	395.00
15000/30000	A	3000 Volts	ESHULE	410.00
5000/7500/10000	A	1000 Volts	ESHUL	362.00
5000/10000/15000	A	1000 Volts	ESHMIP	362.00
5000/15000/30000	A	1000 Volts	ESHMOT	422.00
10000/20000/30000	A	2000 Volts	ESHMUS	422.00
10000/25000/50000	B	2000 Volts	ESHMIX	580.00
5000/10000/15000/20000	A	1000 Volts	ESHMOO	422.00
5000/10000/20000/30000	A	1000 Volts	ESHMEE	450.00
10000/ 20000/30000/40000	B	2000 Volts	ESHMAY	560.00

For Panel Mounting of types A and B cases (standard case with two mounting brackets) add $35.00 to above prices. Correspondence required regarding panel mounting of "C" or "D" cased ESH's.

A zero shifter on the front of the case is recommended if the instrument is to be panel mounted. Additional cost, $25.00.

ADDITIONAL INFORMATION

"Diamond Pivots" and shock mounted jewels are used exclusively in these instruments. This is a revolutionary development in pivot construction pioneered by our progressive engineering staff. These pivots reduce the friction to a completely negligible level. Diamond Pivots will withstand the tremendous impact of a three foot drop without deformation of either the pivot or jewel.

If the Model ESH instrument ("A" or "B" case) is desired to be mounted in a panel, mounting brackets can be attached to the case at an additional cost of $35.00. Correspondence required regarding panel mounting of "C" or "D" cased ESH's. A zero shifter on the front of the case is recommended if the instrument is to be panel mounted. Additional cost, $25.00. (A front zero shifter is standard on the 100 KV instrument.)

The sample scales shown below are representative of the usual ranges of Electrostatic Voltmeters. The ESD and UNIVERSITY instruments up to 1000 v. have a nearly square law scale giving very satisfactory readings down to about 1/3 of the full scale voltage with lowest calibrated point at 1/5 of full scale. Instruments above 1000 volts have scales which tend to close down at the upper end.

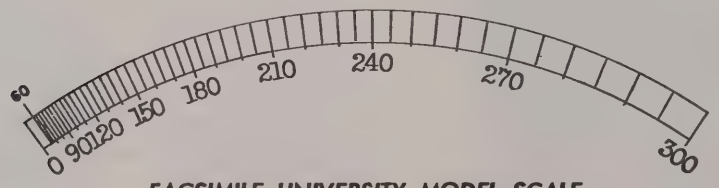
The Model ESH has neither a true square law or linear scale. Its actual configuration is based on the full scale range of the instrument, and the combination of ranges with which it is included. Its lowest calibrated point is about 1/5 full scale.

If the large Model ESH instruments have to be carried about frequently, we can mount metal carrying handles on the case at an additional cost of $15.00. Carrying handles are standard equipment on 100, 75 and 60 kilovolt electrostatic voltmeters.

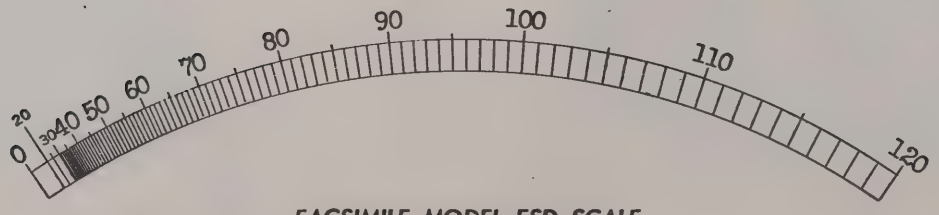
A TRANSIT LOCK feature can be installed in any ESH design instrument at an additional cost of $60.

All Model ESH Electrostatic Voltmeters of 30,000 volts or below can be calibrated to an accuracy of .5%. For a multirange unit, add $50.00 to the price of the instrument for the first range and $35.00 for each additional range. If a single range instrument is ordered add $35.00 to the price of the instrument.

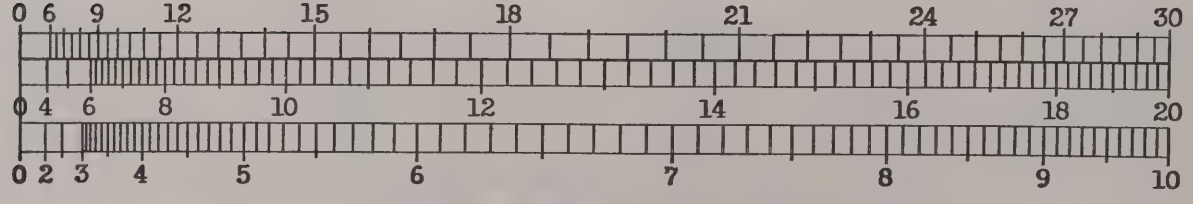
FULL SIZE
ELECTROSTATIC VOLTMETER SCALES



FACSIMILE UNIVERSITY MODEL SCALE



FACSIMILE MODEL ESD SCALE



FACSIMILE MULTIRANGE MODEL ESH SCALE

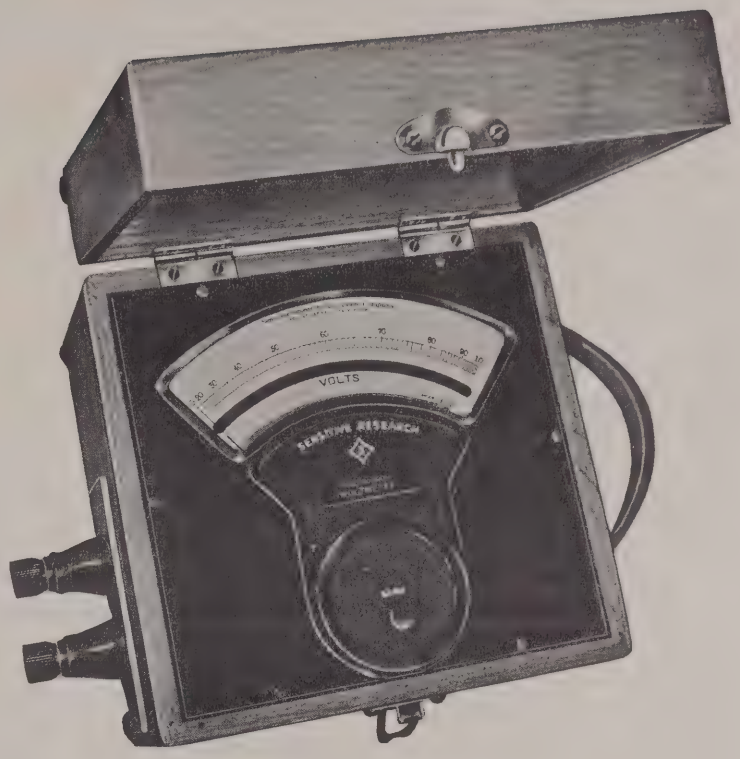
SPECIFICATIONS

HORIZONTAL USE ONLY

ACCURACY	1% (for .5% see pg. 360)
SCALE LENGTH	5.2 inches
SCALE DIVISIONS	75 or 100
PERIOD	3 - 5 seconds
TYPE	Electrostatic
PIVOTS	Diamond
JEWELS	Sapphire Spring Mounted
SHIELDING	Electrostatic
CAPACITY	See below
CASE	Formica
SIZE	7¾" x 7½" x 6 1/16"
INST. WEIGHT	8 lbs.
SHIP. WEIGHT	11 lbs.

FOR PANEL MOUNTING
See page 360

MODEL **ESD**



The Formica case has many advantages over wood; it is structurally stronger, relatively scratch proof, a good moisture barrier, relatively dust proof, and in general better able to withstand adverse field and laboratory conditions. These instruments are all supplied in Formica cases and with diamond pivots.

A MODERN PORTABLE ELECTROSTATIC VOLTMETER

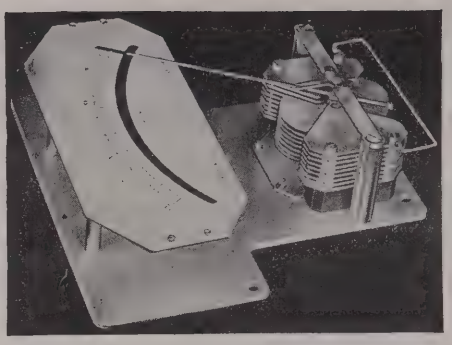
It is well known that electrostatic instruments are essentially voltage measuring devices and the deflection is due to the attraction or repulsion between two electrified surfaces. Such instruments have the advantage that they take no power from the circuit and are free from errors due to magnetic hysteresis, or frequency. They have no self-heating error and the loss of energy in the instrument is negligibly small. They read equally well on alternating or direct current circuits.

While it requires careful workmanship to construct a precise electrostatic voltmeter reading from 1000 volts or higher, the problems of low voltage design are more difficult. The working forces are very low and extreme care must be taken to select even the diamond pivots and shock mounted jewels that must be perfect in all respects, at magnification of 100 diameters.

The rotor is made of duralumin for lightness and strength. The insulation is of selected polystyrene and has an insulation resistance of over 1×10^{15} ohms. The hand drawn scale is 5.2 inches in length, on our standard white enamel finish, with a knife edge pointer moving over a flat mirror to avoid parallax errors in reading. Full scale capacity of the instrument is approximately 22MMFD on the 5000 volt instrument, to 225 MMFD on the 120 volt instrument. They are normally supplied in portable formica cases with brass chrome plated hardware and a heavy carrying strap.

MODEL ESD

Our Electrostatic Voltmeters all use the rugged two pivot method of construction. This rigid method of assembly enables small clearances and strong springs to be used.



120 Volt Instrument
Before Assembly in Case
AIR VANE CHAMBER DAMPING

Single Range (AC - DC)

Full Scale Volts	Code	Prices Portable	In ESDEW-5A Panel Case
† 120	ELECNA	$295.00	$330.00
† 150	ELECMI	280.00	315.00
200	ELECPU	245.00	280.00
300	ELECBA	245.00	280.00
500	ELECFO	210.00	245.00
1000	ELECJY	210.00	245.00
1500	ELECTA	210.00	245.00
2000	ELECCI	210.00	245.00
3000	ELECKO	210.00	245.00
5000	ELECLI	210.00	245.00
6000	ELECHU	235.00	270.00

All single range Model ESD Voltmeters 500 volts and above can be calibrated to an accuracy of .5% for an additional charge of $25.00.

CONDENSER MULTIPLIER RANGES

Additional ranges may be obtained by the use of condenser multipliers.

There is a slight reversal effect on all electrostatic instruments when used on D.C. This effect is not more than 1 volt.

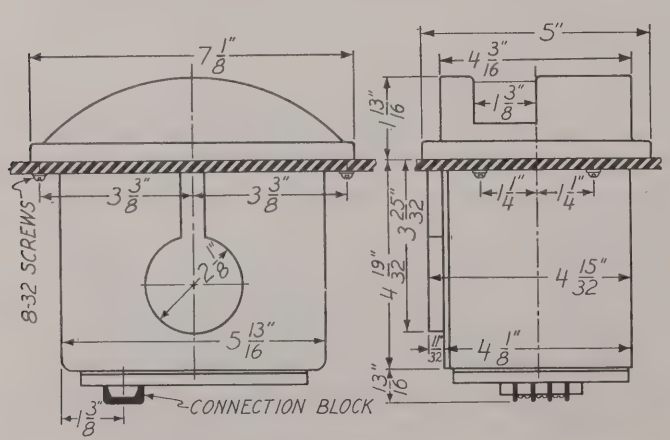
**Multirange (Condenser Type)

Full Scale Volts	Code	Prices Portable	In ESDEW-7A Panel Case with 5" Scale
† 120/240	ELEDA	$345.00	$380.00
† 150/300	ELIFOR	320.00	355.00
† 150/750	ELOHIT	320.00	355.00
250/500	ELUJAK	270.00	305.00
300/1500	ELAKIS	270.00	305.00
500/2000	ELEFTI	260.00	295.00
1000/5000	ELILIK	260.00	295.00
† 125/500/750	ELUNIK	$370.00	$405.00
200/500/1000	ELAPIS	340.00	375.00
300/750/1500	ELERTI	300.00	335.00
500/1500/3000	ELISPO	300.00	335.00
750/1500/5000	ELOTKA	300.00	335.00
1000/3000/6000	ELUVIN	330.00	365.00

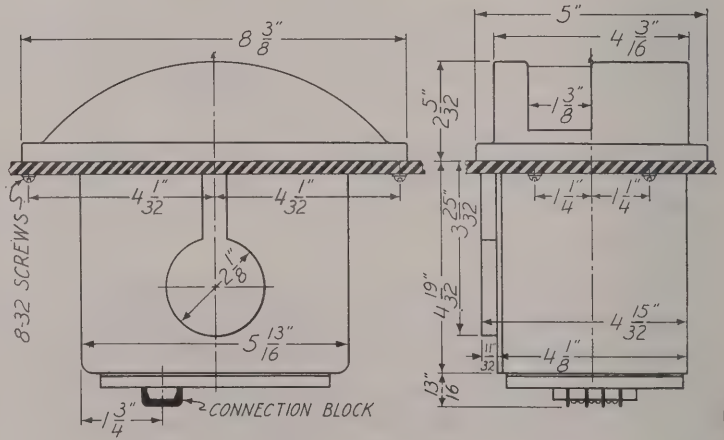
Lowest reading is 1/5 of full scale.
†Accuracy 1½%

**The lowest range can be used on direct or alternating current; upper ranges on alternating only.

We can provide our Model ESD (5" scale) in our edgewise type EW-5A or EW-7A cases for panel mounting *PROVIDED* the metal case and the low side of the instrument connections *CAN BE USED CONNECTED AND GROUNDED TOGETHER.* The Model ESD when supplied as an edgewise panel instrument is called the Model ESDEW-5A or ESDEW-7A. Insulation resistance for EW Case instruments is .5 x 10^{13} ohms minimum for single range instruments.



ESDEW-5A (DEEP CASE) — 5" scale length



ESDEW-7A (DEEP CASE) — 5" scale length

Furnished with binding posts only.

UNIVERSITY MODEL

Double Pivoted Rotor Movement

SPECIFICATIONS

HORIZONTAL USE ONLY

ACCURACY	1%
SCALE LENGTH	4 inches
SCALE DIVISIONS	75 or 100
PERIOD	3 - 5 seconds
TYPE	Electrostatic
PIVOTS	Diamond
CAPACITY	See below
JEWELS	Sapphire Spring Mounted
SHIELDING	Electrostatic
CASE	Moulded bakelite
SIZE	5¼" x 5" x 4⅜"
INST. WEIGHT	4½ pounds
SHIP. WEIGHT	10 pounds

SINGLE RANGE

Full Scale Volts	Code	Price
300	UELENI	$215.00
500	UELPRT	185.00
1000	UELFERT	185.00
1500	UELAMP	185.00
2000	UELELI	185.00
3000	UELEJO	185.00
5000	UELEMI	185.00

DOUBLE RANGE

CONDENSER MULTIPLIER TYPE

*FOR A.C. ONLY

Full Scale Volts	Code	Price
300/1000	UELOAK	$247.00
300/1500	UELOJO	247.00
500/1500	UELOBI	222.00
500/2000	UELOKS	222.00
750/3000	UELOFI	222.00
1000/5000	UELOLK	222.00
2500/5000	UELOJY	222.00

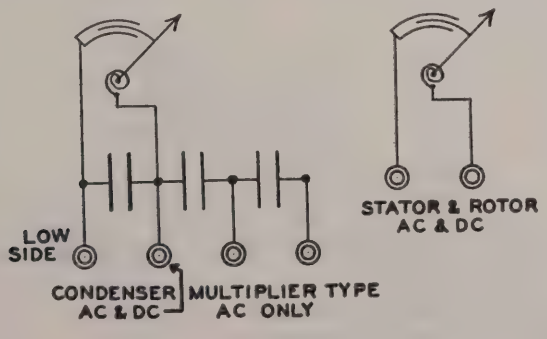
Lowest reading is 1/5 of full scale.

*DC measurements can be made on the lowest range ONLY. All additional ranges are for use on AC only.

There is a slight reversal effect on all electrostatic instruments when used on D.C. This effect is not more than 1 volt.

CONDENSER MULTIPLIER RANGES

Additional ranges are obtained by the use of condenser multipliers in an internal circuit such as shown below.



This University model electrostatic voltmeter has been particularly designed to measure both high and low D.C. and A.C. voltages in circuits where any appreciable current taken by the measuring instrument would introduce considerable error in the true reading. The insulation resistance is 1×10^{15} ohms. It is particularly desirable for use where small size and moderate cost is important.

The case is of molded black bakelite with brass chrome plated hardware. The high side binding post is excellently insulated with polystyrene.

The current consumption on Direct Current is zero and is very minute on alternating current. The instrument is quick reading and the movement is very effectively damped by double vane dampers in almost air tight vane chambers.

The pointer deflects over the customary anti-parallax scale and mirror for precise readings. The instrument is electrostatically shielded.

These electrostatic voltmeters use the rugged two pivot type of construction. This rigid method of assembly enables small clearances and strong springs to be used without the necessity of precisely leveling the instrument before using.

To avoid contact potentials, all of the electrical and working parts must be of the same metal, with a very minimum number of joints, since their resistance would be detrimental in radio frequency measurements. The instrument capacity varies from 225 MMFD on the 300 volt range, to 22 MMFD on the 5000 volt range.

MODEL CRV

The Model CRV is an instrument for the measurement of CREST voltages (also called peak voltages) of either AC or pulsed DC sources. It consists of an electrostatic voltmeter combined in one case with a peak voltage rectifier circuit and switching to allow measurement of either positive or negative peaks, or RMS values. The basic circuit is shown in Fig. 3 at the right.

The range of the instrument is 0 - 1000 volts, the accuracy 1% for recurrent peaks repeating at rates of 20 or more times per second on the "slow" position and at 100 or more times per second on the "fast" range. For full accuracy the duty cycle (width of peak to space between peaks) must not be less than 1 to 2000 and the peak width more than 2 microseconds.

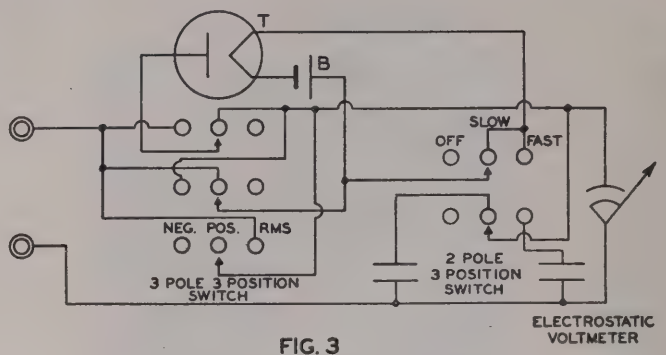


FIG. 3
RMS-CREST VOLTMETER CIRCUIT

The peak rectifier has a battery supplied filament allowing use of the instrument without power line limitations. Battery is readily replaced from the outside of case. The long life peak rectifier has at least an expected life of 1000 hours and can be replaced without affecting calibration.

Multipliers are available for operation up to 100 kilovolts as listed below. These are a combined resistance-capacity type for use on AC and pulsed DC at an accuracy of 1%. These multipliers are also usable for intermittent operation on pure DC with an accuracy of 3%. Multipliers are individually calibrated with each instrument. If they are not ordered with the instrument, but at some later date to increase its range, the instrument must be returned to the factory for calibration with the multiplier. Calibration curves are normally supplied. Separate scales may be drawn on the instrument for additional ranges at a cost of $50.00 per scale.

CREST VOLTMETER

FOR

READING TRUE RMS, NEGATIVE PEAKS AND POSITIVE PEAKS

RANGES Basic instrument 0-1 Kilovolt. External multipliers available up to 100 Kilovolts. A maximum of 4 scales, including the basic 1 KV range, may be provided.

ACCURACY 1% of full scale for RMS and for peaks of 100 per second and faster on "Fast" position or, 20 or more per second on "Slow" position.

SCALE LENGTH 5.2 inches.

PIVOTS Diamond

ELECTROSTATIC SHIELDING is standard.

INPUT IMPEDANCE
RMS = 10,000 megohms and 25 micro microfarads.
Positive Peak = 10,000 megohms and 15 micro microfarads.
Negative Peak = 10,000 megohms and 15 micro microfarads.

CASE Formica

PHYSICAL DIMENSIONS
Basic instrument 13¾" x 7½" x 6½".
50 KV range multipliers 12" x 9" x 27½".
Other ranges proportionate in height with range of multipliers. Additional correspondence required for special panel mounting.

Basic instrument — Code CREST — Price $498.00

MULTIPLIERS

RANGE	CODE	PRICE	RANGE	CODE	PRICE
100 KV	CRABE	$395.00	30 KV	CRUGI	$225.00
75 KV	CRECT	310.00	20 KV	CRYJU	215.00
50 KV	CROFA	250.00	10 KV	CRAAK	210.00
40 KV	CRFAO	235.00	5 KV	CREEL	205.00

MULTIPLIERS Resistance-capacitor divider type for AC or pulsed DC at 1% and 3% on DC.
Input impedance — Varies with the full scale range used.

EXAMPLE (1) 2 KV = .001 mfd. & 50 megohms.
(2) 100 KV = .000025 mfd. & 500 megohms

MODEL AEW-7A

MODEL RF

S. STERLING CO.
Manufacturers' Representatives
3300 SOUTH DIXIE DR.
DAYTON 39, OHIO
AX 8-7573

Portable and Panel
AC/DC AUDIO & RADIO FREQUENCY
THERMOCOUPLE
MILLIAMMETERS, AMMETERS, VOLTMETERS

Model	Description	Maximum Frequency	Page
	"About Thermocouple Instruments"		402-403
	Mounting Dimensions for Edgewise Panel Cases		403
A	.5% and .75% Milliammeters and Voltmeters. 6.3" scale length	15 kc	404-405
AU	.5% and .75% Milliammeters and Voltmeters. 6.3" scale length	35 kc	406
AUV	(See Model AU Voltmeters. Page 406)		
RF	.5% and .75% Milliammeters and Voltmeters, 1% Ammeters. 6.3" scale length	20 mc	407-410
RFV	(See Model RF Voltmeters. Pages 409-410)		
XT	(See Model RF Ammeters. Page 409)		
	Radio Frequency Measurements Using a DC Millivoltmeter and External Thermocouples	10 mc	410-411
T	Mounted Insulated Vacuum Thermocouples. (Also see Section 10)	10 mc	411
TX	Heavy Current Air Thermocouples	20 mc	411
TM	Multirange Vacuum Thermocouple Unit	100 kc	411
University	.75% Compact Milliammeters and Voltmeters. 4" scale length	7.5 kc	412

Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N. Y.

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

Symbol of Quality

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *Electrical Measuring Instruments Since 1927*

ABOUT THERMOCOUPLE INSTRUMENTS

GENERAL CHARACTERISTICS

Electrical indicating instruments that employ a thermoelement as a converter offer the user significant advantages in frequency response and sensitivity over other AC types with true rms response. They can be used with equal facility and accuracy on DC and AC from 7 cps to 20 mc, and in instances where UHF thermal converters are employed, this frequency range can be extended to over 100 mc. Thermocouple instruments have long served as a standard in the indication of frequency influence. They have true rms response regardless of waveform. Relatively high sensitivity makes it convenient to offer multirange instruments starting with full scale values as low as 200 mv and 1 ma and going on up to 1500 v and 100 amps. (Instruments can be supplied with external multipliers to extend voltage ranges.)

Sensitive Research thermoelements have excellent AC/DC transfer characteristics. They are selected for their low reversal effect. Consequently, guarantee of accuracy is the same for both AC and DC. Instruments that incorporate thermocouples can be calibrated directly on DC and only their AC/DC difference, or frequency influence, has to be checked by AC transfer methods.

AUTOMATIC OVERLOAD PROTECTION

The design of thermocouples and their basic indicators has developed to the point where most of the limitations that were formerly imposed on their application no longer are a major consideration. Automatic overload protection is included whenever possible for the safeguarding of thermocouples. Percent of overload protection varies according to range and sensitivity and is listed in the specifications of individual instruments. The protection system uses semiconductor circuits to automatically shunt the current around a thermocouple if currents exceed normal full scale values. It preserves the full advantages of thermal type instruments, e.g., true rms response, high frequency operation, and high sensitivity. However, in square loop magnetic material testing or in noise measurements, if sharply peaked waves are imposed, the instrument begins to clip the top of the spikes at a peak to rms ratio of approximately 4 to 1. Hence, waves with greater than this peak to rms ratio tend to read low. Therefore, to preserve versatility, the operator may easily disconnect the protection system from the measuring circuit if he so desires.

THERMOCOUPLE REPLACEMENT

A Thermocouple Replacement Feature (TRF) Type 357, (see photo) is normally supplied and included in the price of all Model A and AU instruments. Its installation allows for the field replacement of overloaded or burned out thermocouples with the retention of full instrument accuracy. Type 357 replacement thermocouples are furnished with two calibrated fixed resistors which must be soldered into place by the user.

The Type 362 (Fig. 1, pg. 403) is a new optional thermocouple replacement feature presently only available for Model A instruments with a sensitivity of 100 Ω/v or a lowest range of 10 ma. Replacement can be made by "plug-in" instead of soldering. A variable sensitivity resistor is provided to enable the user to adjust full scale deflection of the instrument for maximum accuracy.

Replacement thermocouples are supplied with a correction chart (Fig. 2, pg. 403) for proper scale linearity. Most corrections are within the accuracy tolerance of the instrument in which they are to be replaced. If spare thermocouples are ordered at the time of purchasing an instrument, they can be matched for maximum replacement accuracy. Type 362 replacement thermocouples seldom require correction charts.

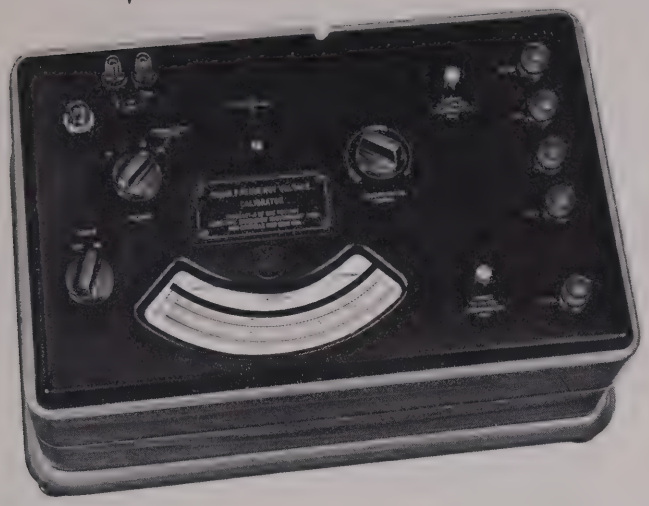
Replacement thermocouples can be ordered by specifying the Replacement Thermocouple type number, and when designed for use with existing instruments in the field, the instrument serial number. Replacement thermocouple types, either 357 or 362, are identified for users in the field by a black and silver metallic label mounted adjacent to the thermocouple feature. In older instruments the replacement feature may exist but be unidentified. Such an instrument should be returned for conversion to the present design. Delivery of spare thermocouples is from stock.

UNMOUNTED
VACUUM THERMOCOUPLE

The reader is also referred to Section 2 which describes thermocouple type Polyrangers with as many as 88 ranges.

Vacuum Thermocouples of all types are listed separately in Section 10.

TYPE 357 THERMOCOUPLE REPLACEMENT FEATURE



Model RFVC, a Thermocouple type standard for the calibration of VTVM's from DC to 10 mc. See Section 1.

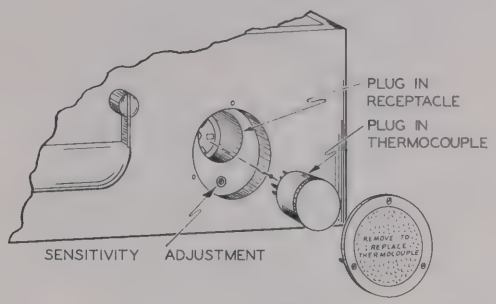


Figure 1. Type 362 "Plug-in" Thermocouple Replacement Feature

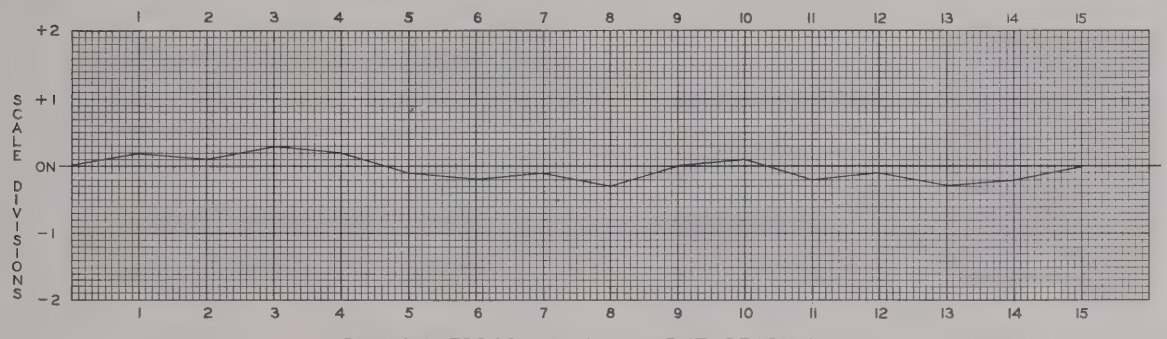


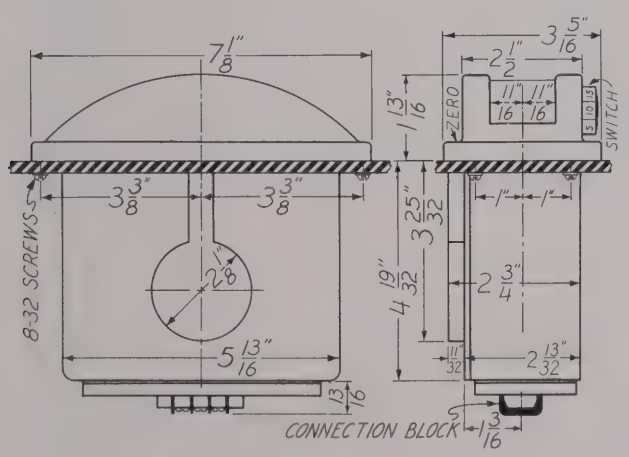
Figure 2. Correction Chart Furnished with Replacement Thermocouples

MOUNTING DIMENSIONS FOR EDGEWISE PANEL INSTRUMENTS

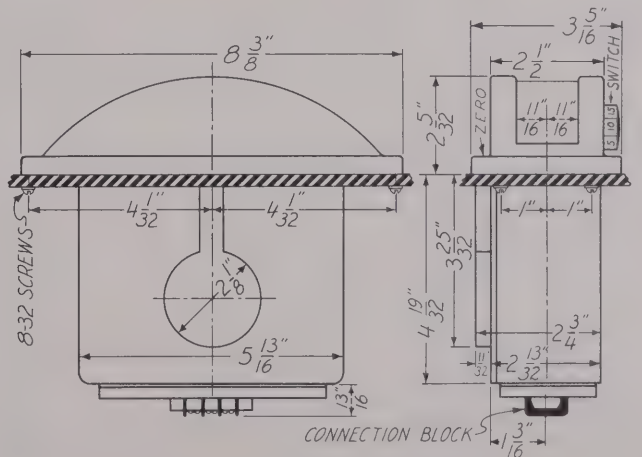
All Model A instruments, Model AU milliammeters and Model RF milliammeters can be supplied in Type EW-5A or EW-7A cases for flush vertical panel mounting. Binding posts or connection lugs are furnished in the rear. Cases are of die cast aluminum with a black wrinkle finish. Switches, when supplied, are as indicated in the drawings. (See individual portable model specifications.) External zero shifters are supplied on the front of all cases.

NOTE

The Types EW-5A and EW-7A replaced the Types EW-5 and EW-7 in May, 1961. There are minor dimensional differences between the two types. For purposes of exact replacement, the Types EW-5 or EW-7 can be supplied at no additional charge, *but must be specified at time of ordering.*

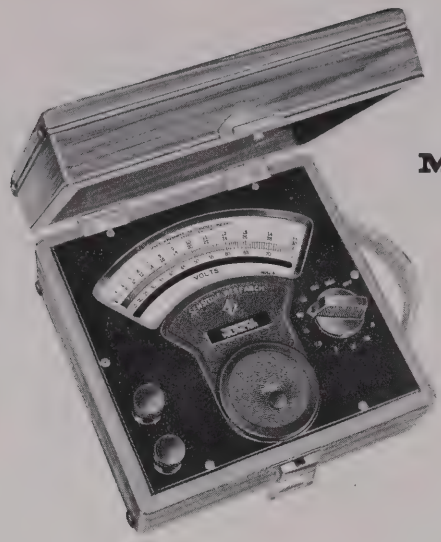


TYPE EW-5A SHALLOW CASE, Scale Length 5" for Model A, and AU and RF Milliammeters



TYPE EW-7A SHALLOW CASE, Scale Length 7" for Model A, and AU and RF Milliammeters

MODEL A THERMOCOUPLE MILLIAMMETERS & VOLTMETERS



MODEL A

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale; .75% for instruments with a basic sensitivity of 3 ma or 500 Ω/v, or higher
FREQUENCY	DC and 7 cps up to 15 kc max. Frequency specifications for individual instruments listed with ranges.
TYPE	Thermocouple; permanent magnet, double pivoted moving coil; true rms response
SENSITIVITY	Voltmeters: 100 Ω/v or 500 Ω/v as specified. Approx. resistances of milliammeter ranges listed below.
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
THERMOCOUPLE REPLACEMENT FEATURE	Type 357 (Type 362 optional.)
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	7 lbs. net; 10 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

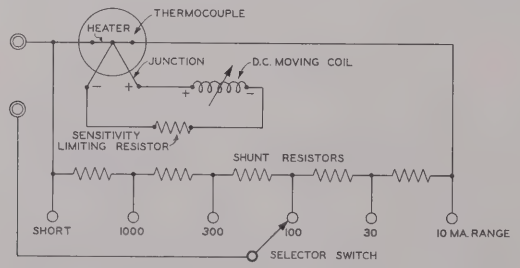


FIGURE 1. MULTIRANGE MILLIAMMETER CIRCUIT

OPTIONAL SPECIFICATIONS

1. A "Plug-in" Thermocouple Replacement Feature (TRF), Type 362, can be furnished instead of the Type 357. (In the Type 357, thermocouples are soldered into place.) It can be supplied in all milliammeters with a lowest range of 7.5, 10, 15 or 20 ma, and all voltmeters with a sensitivity of 100 Ω/v. The Type 362 system includes a variable resistor to adjust the full scale output of the thermocouple for optimum scale linearity. Both types of replacement features are described more fully on pages 402-403.

If the Type 362 "Plug-in" Thermocouple Replacement Feature is desired, specify and add $25.00 to the price of the portable or edgewise panel instrument selected.

2. Instruments with special scales and/or ranges are available. Multirange instruments are normally switch controlled to 3 amps and 1000 v (500 v maximum between switch positions). Voltmeters are normally offered with a highest sensitivity of 500 Ω/v but can be supplied in special instances with sensitivities of 750 or 1000 Ω/v depending on the lowest volt range, frequency response and accuracy required. Correspondence is necessary on all special instruments.

3. Instruments with a lowest range of 3 ma or less or a sensitivity of 500 Ω/v on special order can be supplied with a fundamental accuracy of .5%. Correspondence required.

OPTIONAL ACCESSORIES

1. Spare thermocouples for installation in the field can be ordered with the Model A. If ordered after the instrument is in service, the type number of the feature and the serial number of the Model A must be specified. (Reference page 402.)

Replacement Thermocouple	Price
Type 357	$60.00
Type 362	75.00

2. Voltage ranges can be extended by the addition of external multipliers. If multipliers are ordered with the Model A, they can be calibrated together, and overall accuracy is guaranteed within the accuracy of the instrument. When ordering multipliers to extend voltage ranges, specify frequency at which measurements are to be made. Shunts cannot be provided for the extension of current ranges because their addition creates variations in scale linearity. Higher current ranges can be obtained by using the Model TR, Type 1 Transformer in conjunction with any instrument range from 2 to 5 amps. Accessory measuring units such as multipliers and transformers are described in Section 10.

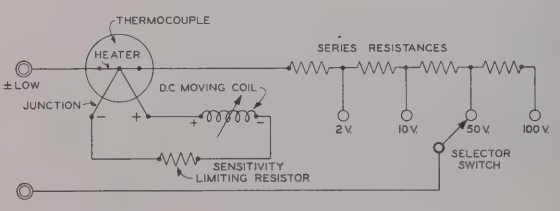


FIGURE 2. MULTIRANGE VOLTMETER CIRCUIT

MODEL A THERMOCOUPLE MILLIAMMETERS & VOLTMETERS

GENERAL DESCRIPTION

The Model A series consists of AC/DC multirange milliammeters and single range or multirange voltmeters. They are designed primarily for AC applications in the medium audio range. (Single range milliammeters have a relatively flat frequency response up to 1 mc and are listed under the Model RF on page 408.) If desired, they can be used at reduced accuracy with repeatable results over a wider frequency span than listed. (See figures 1 and 2.)

An Automatic Thermocouple Overload Protection system is installed in all milliammeters with a lowest range of 20 ma or less and all voltmeters. Instruments with a lowest range not exceeding 3 ma, or a sensitivity of at least 500 Ω/v, are protected for overloads of 5000%, or twice the highest current range for ranges of 100 ma or more, and 500 v above rated voltage. Instruments with a lowest range of 5 to 20 ma, or a sensitivity of 100 Ω/v or 200 Ω/v, are protected for overloads of 500% or twice the highest current range for ranges of 100 ma or more, and 500 v above rated voltage. Either the percentage overload figures or the actual values apply, whichever is the lesser amount.

A manually operated thermocouple overload protection system is incorporated in all milliammeters with a lowest range above 20 ma and up to and including 200 ma. Thermocouples are safeguarded for overloads of 1000% during initial operation. A "Press to Read" button can be locked, if desired, while making measurements. (If specified, at no extra charge, a non-locking type button can be incorporated.) When the button is depressed, 80% of the input is shunted around the thermocouple. A red "Safety Line" is marked at the 20% scale point. The range value is correct if the deflection of the instrument is below the red line. The loading of the circuit by the instrument is constant regardless of the position of the push button.

Instruments without thermocouple protection can withstand overloads of 100%. On ranges of 500 v or more, the limitation is 500 v above rated voltage.

All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Portable cases made of tough, durable formica are gasketed to provide an effective dust and humidity barrier.

PANEL MOUNTED INSTRUMENTS

The Model A is also available for vertical panel mounting in the shallow EW-7A (7″ scale length) or EW-5A (5″ scale length) edgewise panel case. Case dimensions are diagramed on page 403.

Performance characteristics are the same as listed for the portable type except as follows:

1. The possible introduction of stray capacitance from grounding the case necessitates reducing frequency limits in some instances. Ranges of 20 v and above have a frequency span of 50% of normal. Correspondence is recommended if the instrument is to be used at higher frequencies.

2. The Thermocouple Replacement Feature (TRF) is mounted on the rear of the case.

3. Multirange instruments can have a maximum of 8 ranges switch controlled (only 7 ranges if either a "Short" or "Open" position is desired); the remainder must be supplied on terminals.

4. Type EW-5A cased instruments are limited to a maximum of 100 scale divisions.

5. Manually operated overload protection is not available.

Specify: Model AEW-5A or AEW-7A and code word of portable instrument having ranges desired.

Price: Add $25.00 to price of code word selected.

MILLIAMMETERS

Frequency: a) Instruments with lowest range of 3 ma and below; DC and 7 cps to 7.5 kc at .75% accuracy.
b) Instruments with lowest range of 5 ma or more; DC and 7 cps to 15 kc at .5% accuracy.
(Ranges of 1 amp and higher limited to 4 kc. Accuracy above 4 kc to 10 kc is .75%.)

Range	Approx. Resist. Ω	Scale Div.	Code	Price
2/10/50/100/500	640/538/124/63/13	100	AMILKO	$390.00
5/10/50/100/500	242/148/34/17/3.5	100	AMILSA	374.00
10/50/100/500/1000/2000	30/21/12/2.4/1.2/.6	100	AMILUR	390.00
20/100/200/500/1000	10/3.6/2/.8/.4	100	AMILTI	374.00
50/100/200/500/1000/2000	5/3.8/2.5/1/.5/.25	100	AMILKU	390.00
2/5/10/20/50/100/200/500/1000	640/870/538/295/124/63/32/13/6.4	100	AMILWA	408.00
3/7.5/15/30/75/150/300/750/1500	500/440/260/140/60/30/15/6/3	150	AMILTY	408.00
5/10/20/50/100/200/500/1000	242/148/81/34/17/8.8/3.5/1.8	100	AMILBO	399.00
10/20/50/100/200/500/1000/2000	30/38/21/12/5.8/2.4/1.2/.6	100	AMILAC	399.00
15/30/75/150/300/750/1500	20/20/10/5.8/3/1.2/.6	150	AMILDA	391.00

VOLTMETERS

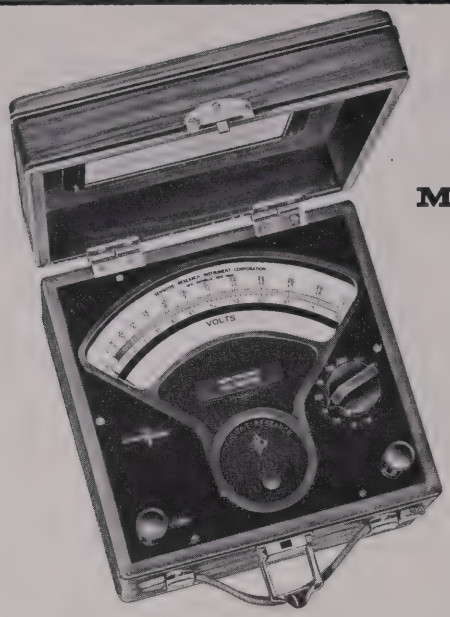
Frequency: a) Instruments with sensitivities of 100 Ω/v; DC and 7 cps to 7 kc at .5% accuracy, except ranges of 300 v or higher limited to 5 kc.
b) Instruments with sensitivities of 500 Ω/v; DC and 7 cps to 5 kc at .75% accuracy, except ranges of 300 v or higher limited to 3 kc.

Any single range instrument with a sensitivity of 100 Ω/v, from .2 v to 300 v full scale, price $311.00; over 300 v to 1000 v, price $330.00. When sensitivity is 500 Ω/v, ranges from 1.5 v to 300 v, price $341.00; over 300 v to 1000 v, price $360.00.

Range	Code	Scale Div.	Price 100 Ω/v	Price 500 Ω/v
.2/1/5/20	AVALMA	100	$362.00	———
.5/2/10/50	AVOLNO	100	362.00	———
1.5/7.5/30/75	AVOLOP	150	362.00	$388.00
5/20/50/100	AVOLPY	100	362.00	388.00
10/50/200/500	AVOLSY	100	383.00	396.00
15/75/300/750	AVOLTO	150	388.00	402.00
1.5/3/7.5/15/30/75/150	AVOLKA	150	401.00	418.00
2/5/10/20/50/100/200	AVOLBI	100	401.00	418.00
7.5/15/30/75/150/300/750/1500	AVOLCU	150	422.00	469.00
.3/.75/1.5/3/7.5/15/30/75/150/300	AVOLUM	150	404.00	———
1.5/3/7.5/15/30/75/150/300/750	AVOLVO	150	404.00	459.00
2/5/10/20/50/100/200/500/1000	AVOLWY	100	409.00	464.00

When ordering voltmeters, specify Ω/v desired.

MODEL AU—AUDIO FREQUENCY THERMOCOUPLE MILLIAMMETERS & VOLTMETERS



MODEL AU

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale; .75% for instruments with a basic sensitivity of 2 ma or 500 Ω/v or higher
FREQUENCY	DC and 7 cps to 35 kc max. Frequency specifications listed with ranges
TYPE	Thermocouple; permanent magnet, double pivoted moving coil; true rms response
SENSITIVITY	Voltmeters: 200 Ω/v, 500 Ω/v or 750 Ω/v as specified. Approx. resistances of milliammeters listed with ranges
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
THERMOCOUPLE REPLACEMENT	Type 357
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" l x 7½" w (Milliammeters 4⅝" h; voltmeters 6⅛" h); bakelite panel; hinged cover; handle
APPROX. WEIGHT	7 lbs. net; 12 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. Special scales and/or ranges available.

OPTIONAL ACCESSORIES

1. Spare thermocouples available for field replacement. **Specify:** Replacement Thermocouple Type 357. **Price:** $60.00. (See pages 402-403.)

2. Voltage ranges can be extended by the addition of external multipliers. If multipliers are ordered with the Model AU they can be calibrated together, and, depending on the frequency range required, overall accuracy is within the accuracy of the instrument. Correspondence necessary.

GENERAL DESCRIPTION

The Model AU consists of AC/DC multirange milliammeters or voltmeters for measurements over the entire audio frequency range and up to 35 kc. If desired they can be used at reduced accuracy, with repeatable results, over a wider frequency span than listed.

An Automatic Thermocouple Overload Protection system is installed in all instruments. Instruments with a lowest range of 2 ma or less, or a sensitivity of 500 Ω/v or more, are protected for overloads of 5000% or twice the highest current range for ranges of 100 ma or more and 500 v above rated voltage. Instruments with a lowest range of 5 ma or higher (20 ma max.), or 100 Ω/v or 200 Ω/v, are protected against overloads of 500% or twice the highest current range for ranges of 100 ma or more and 500 v above rated voltage. Either the percentage overload figures apply or the actual values, whichever is the lesser amount.

PANEL MOUNTED INSTRUMENTS

Model AU milliammeters only are also available for vertical panel mounting in the shallow EW-7A (7″ scale length) or EW-5A (5″ scale length) edgewise panel case. Case dimensions are diagramed on page 403.

Performance characteristics are the same as listed for the portable type except as follows:

1. The Thermocouple Replacement Feature (TRF) is mounted on the rear of case.

2. Multirange instruments can have a maximum of 8 ranges switch controlled (only 7 ranges if either a "Short" or "Open" position is desired); the remainder must be supplied on terminals.

3. Type EW-5A cased instruments are limited to a maximum of 100 scale divisions.

Specify: Model AUEW-5A or AUEW-7A and code word of portable instrument having ranges desired.

Price: Add $25.00 to price of code word selected.

Note: Panel mounted thermocouple voltmeters are offered only in the Model A (pages 404-405). They cannot be supplied in the Model AU because of the possible introduction of stray capacitance when grounding the edgewise panel case.

MILLIAMMETERS

Frequency: a. Instruments with lowest range of 1.5 ma or 2 ma; DC and 7 cps to 15 kc at .75% accuracy. b. Instruments with lowest range of 5 ma or 10 ma; DC and 7 cps to 20 kc at .5% accuracy. (1 amp range of multirange instruments limited to 10 kc. Between 10 kc and 20 kc accuracy .75%.)

Range	Approx. Resist. Ω	Scale Div.	Code	Price
1.5/5/15/50/150	1000/320/136/44/15	150/100	AULYB	$430.00
2/10/50/100/500	800/200/48/25/5	100	AUDOM	425.00
5/10/50/100/500	65/270/90/50/10	100	AUDIT	415.00
10/20/100/200/500	139/37.5/12/5.8/2.4	100	AUTIM	415.00
10/50/200/500/1000	30/21/5.8/2.4/1.2	100	AUGOM	415.00

VOLTMETERS

Frequency: a. Instruments with a sensitivity of 500 Ω/v or 750 Ω/v; DC and 7 cps to 35 kc at .75% accuracy. b. Instruments with a sensitivity of 200 Ω/v; DC and 7 cps to 35 kc at .5% accuracy.

Range	Ω/v	Scale Div.	Code	Price
1.5/3/7.5/15/30/75/150/300/750	200	150	AUVOLT	$470.00
2/5/10/20/50/100/200/500	200	100	AUVOMO	440.00
1.5/7.5/15/30/75/150	500	150	AUVONI	435.00
2/5/10/20/50/100/200	500	100	AUVOOP	445.00
3/7.5/15/30/75/150	750	150	AUVOPF	475.00
5/10/20/50/100	750	100	AUVORP	460.00

MODEL RF RADIO FREQUENCY THERMOCOUPLE INSTRUMENTS

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale excepting .75% for ranges of 2 ma or less and all multirange milliammeters. 1% for ammeters
FREQUENCY	DC and 7 cps to 20 mc max.
TYPE	Thermocouple; permanent magnet, double pivoted moving coil; true rms response
SENSITIVITY	Voltmeters: Approx. 200 Ω/v Approx. resistances of milliammeter ranges listed below
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Automatic temperature compensation from 20°C to 30°C
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; black bakelite panel; carrying handle
SIZE & APPROX. WEIGHT	Single range milliammeters: 7¾" x 7½" x 4⅝" h.; 7 lbs. net; 10 lbs. shipping Multirange milliammeters: 7¾" x 7½" x 6⅛" h.; 8 lbs. net; 11 lbs. shipping Single range voltmeters: 7¾" x 7½" x 4⅝" h.; 7 lbs. net; 10 lbs. shipping Multirange voltmeters: 13¾" x 7½" x 6⅜" h.; 10 lbs. net; 19 lbs. shipping Ammeters: 7¾" x 7½" x 4⅝" h.; 7 lbs. net; 10 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

Instruments with special ranges and/or scales can be supplied. In some instances instruments can be guaranteed for higher accuracy than rated, if for use over a narrower frequency span. Conversely, instruments can be employed over a wider frequency span at reduced accuracy. Correspondence required.

PANEL MOUNTED INSTRUMENTS

Model RF single and multirange milliammeters are also available for vertical panel mounting in the deep EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 403.

Performance characteristics are the same as listed for the portable type excepting as follows:

1. Frequency range limited to 500 kc for single range instruments and 100 kc for multirange instruments.

2. Type EW-5A cased instruments are limited to a maximum of 100 scale divisions.

Specify: Model RFEW-5A or RFEW-7A and code word of portable instrument having ranges desired.

Price: Add $25.00 to price of code word selected.

Note: Panel mounted thermocouple voltmeters are offered only in the Model A. (See pages 404-405.)

MODEL RF

GENERAL DESCRIPTION

The Model RF, consisting of AC/DC milliammeters, ammeters and voltmeters, is designed for applications demanding accurate true rms measurements over a wide range of radio frequencies. Typical applications are the checking of oscillators, signal generators and electronic voltmeters, and making frequency response tests on thermocouples and thermocouple instruments.

There are some basic variations in construction between the Model RF instruments listed depending on what they are to measure, and this results in their having dissimilar case sizes, and in certain instances, specifications. As an example, multirange milliammeters employ 4 individual thermocouples with the junction circuits completely switch controlled (Fig. 1, pg. 408). This circuit is more complex than single range milliammeters or multirange milliammeters for use over a narrower frequency span that are constructed with a single thermal element shunted to obtain additional ranges. Ammeters utilize air thermocouples rather than vacuum types. Their heavy wattage dissipation makes it advisable to furnish their thermal element attached externally to the instrument case as shown. (Note that circuit connections are made directly to the heater of the air couple.) Dual range ammeters are supplied with an additional thermocouple of the same type attached to the opposite side of the case. Multirange voltmeters are furnished in a larger case than current measuring instruments in order to accommodate a circuit configuration that allows all ranges to be switch controlled with a minimum frequency influence (Fig. 4, pg. 410). In switching ranges, all resistances and wiring other than that associated with the range in use, are isolated from the circuit.

MODEL RF
RADIO FREQUENCY MILLIAMMETERS

An automatic thermocouple overload protection system is installed in all single range milliammeters with a range of 20 ma or less and all voltmeters as follows:

(1) Ranges of 2 ma or less are protected for overloads of 5000%.

(2) Ranges of 5, 7.5, 10, and 20 ma are protected for overloads of 500%.

(3) All voltmeters are protected for overloads of 500% or 500 v above rated voltage, whichever is the lesser figure.

(4) Instruments with a lowest range of more than 20 ma but not more than 200 ma can be provided with a manually operated 1000% overload protection circuit for use during initial operation. Frequency span is reduced to 100 kc. Installation is optional and must be specified at time of ordering. Instruments without overload protection can withstand overloads of 100%, excepting ammeters which are rated for 50%.

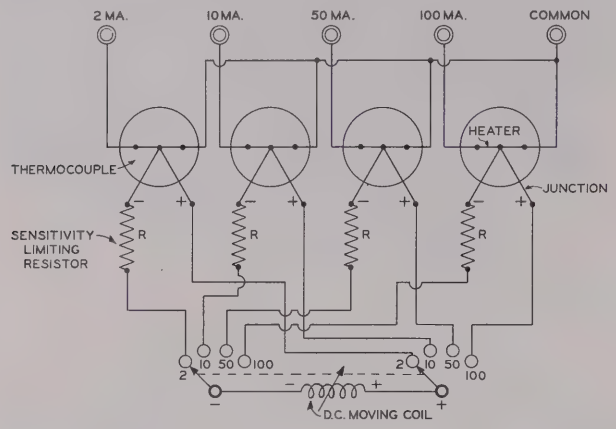


Fig. 1. MODEL RF MULTIRANGE MILLIAMMETER CIRCUIT

SINGLE RANGE MILLIAMMETERS

Frequency: a) Instruments with a range of 2 ma or lower; DC and 7 cps to 1 mc at .75% accuracy.
b) Instruments with a range of 5 ma to 500 ma; DC and 7 cps to 1 mc at .5% accuracy.

Range	Approx. Heater Resist. Ω	Scale Div.	Code	Price
1.0	2000	100	RAMIL	$313.00
1.5	1000	150	RABIT	293.00
2	800	100	RADAN	280.00
5	80	100	RACER	275.00
7.5	40	150	RAMON	275.00
10	20	100	RANOR	275.00
20	10	100	RAVIN	275.00
50	5	100	RACON	275.00
100	2	100	RADIT	275.00
200	.5	100	RACUM	275.00
300	.4	150	RADUM	275.00
500	.3	100	RAFUS	275.00

While all thermocouple instruments make excellent AC/DC transfer standards, the Model RF is particularly valuable in such usage because of its flat response from DC through a wide range of radio frequencies. It can be used to determine AC/DC differences (or the influence of frequency when referenced to DC) by standardizing a single point on DC by means of a potentiometer and then applying an equivalent AC of the same value. The short term stability in such applications is well above rated accuracy, and with good technique the instrument can be relied on to repeat its readings within its resolution.

Possible capacitance effects from grounding prohibit supplying Model RF voltmeters in an edgewise panel case. A thermocouple replacement feature is not available in any instrument. However, uncalibrated spare thermocouples can be provided if the user's facilities permit installation and recalibration in the field. This calibration can be done on direct current. When ordering spare thermocouples, specify the serial number of the instrument in which they are to be installed. Prices are listed in Section 10.

All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element that will withstand abnormal handling. Cases, made of tough, durable formica, are gasketed to provide an effective dust and humidity barrier.

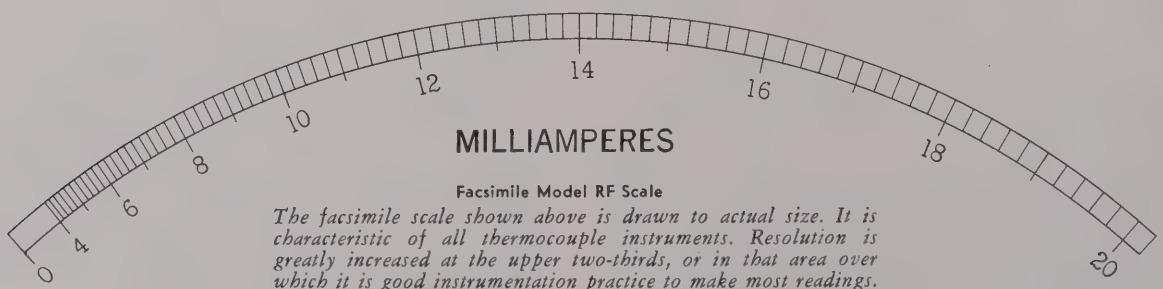
MULTIRANGE MILLIAMMETERS

Note 1. Each thermocouple is in an isolated circuit and has an individually calibrated scale. Ranges out of service because of thermocouple burnout do not affect usage of remaining ranges. Instruments with a 1 amp range use a contact type air thermocouple.

Frequency: a) Ranges of 2 ma or less; DC and 7 cps to 250 kc at .75% accuracy.
b) Ranges of 5 ma or higher; DC and 7 cps to 250 kc at .5% accuracy.

Range	Approx. Heater Resist. Ω	Scale Div.	Code	Price
1/5/20/50	2000/80/10/5	100	RIJKO	$380.00
2/10/50/100	800/20/5/2	100	RIKLA	362.00
2/10/25/100	800/20/8/2	100/125	RILMI	362.00
2/5/25/50	800/80/8/5	100/125	RIMNU	362.00
2/10/100/200	800/20/2/.5	100	RIMOS	362.00
10/25/50/100	20/8/5/2	100/125	RIOPO	357.00
10/50/100/1000	2/5/2/.1	100	RIPRY	357.00
25/50/100/500	8/5/2/.3	125/100	RIRSU	357.00
50/200/500/1000	10/.5/.3/.1	100	RISTY	357.00
*10/10/10/10	20/20/20/20	100	RISTO	357.00
*2/2/10/10	800/800/20/20	100	RITUK	367.00

**2 or 4 identical ranges are offered for applications where the instrument must be kept in continuous service and cannot always be returned immediately for a replacement thermocouple.*



Facsimile Model RF Scale

The facsimile scale shown above is drawn to actual size. It is characteristic of all thermocouple instruments. Resolution is greatly increased at the upper two-thirds, or in that area over which it is good instrumentation practice to make most readings.

AMMETERS

Frequency: DC and 7 cps to 20 mc at 1% accuracy.

Note 1. Double range instruments can be supplied. A second range can be selected from any of the heavy current air thermocouples listed on page 411. Order by specifying the Model RF and add the letter "-D" to the code word of the single range instrument desired. Specify the code word of the air thermocouple and its range in amps. Add the price of the air thermocouple plus $75.00 to the price of the single range instrument selected. Double range Model RF ammeters are provided with an individually calibrated scale for each thermocouple. Input to the instrument is via either set of thermocouple heater wire terminals and a switch is provided to connect either of the junction leads to the moving element.

Range	Scale Div.	Code	Price
1	100	TARIK	$312.00
2	100	TALEM	312.00
5	100	TASIS	312.00
10	100	TAMOR	318.00
20	100	TAKIM	329.00
30	150	TAFOR	337.00
50	100	TABEL	359.00
100	100	TACZX	484.00

MODEL RF VOLTMETERS

The Model RF voltmeter utilizes specially designed switching to increase its operating frequency range considerably beyond the limits listed for other multirange self-contained thermocouple models. Figure 2 shows the effective circuit of a multirange voltmeter made for measurements in the low to medium audio range. Part of the effective stray capacitances are shown as C_1 to C_6. C_1, C_2, C_3, and C_4 (the switch and lead capacities) are directly across the individual series resistance sections and hence seriously affect frequency response. The errors from these stray capacitances are significant to the point that without changes in circuit layout any improvement in the frequency response of the multiplying resistors themselves is of little value.

In the Model RF voltmeters the series resistors in the multiplier chain are a deposited metal film type with a relatively flat frequency response well beyond 10 megacycles and excellent long term stability. In order to make the most of this characteristic the effective circuit shown in Figure 3 is employed. (Figure 4 shows the complete circuit.) In this configuration the capacity C_1 is no longer shunting R_1. C_1 and C_4 are in series with R_2 and the series capacitor chain is shunting R_1. This reduces stray capacitance errors by a factor of more than two to one. Special attention given in assembly to placement of the wiring, low capacity switches, resistors with excellent frequency response characteristics and a circuit design with low effective stray capacitance, all add up to an AC/DC voltmeter for precision operation in the radio frequency range.

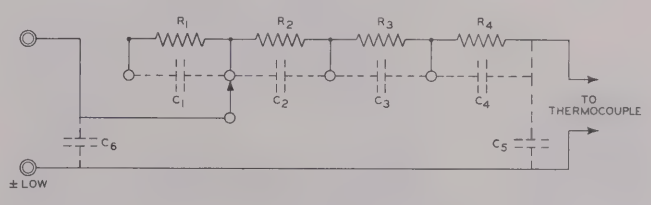


Figure 2.

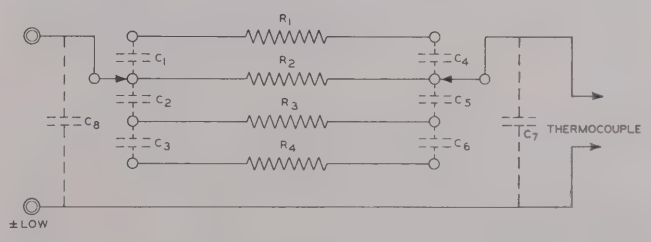


Figure 3.

RADIO FREQUENCY VOLTMETERS

DC MILLIVOLTMETERS & EXTERNAL THERMOCOUPLES

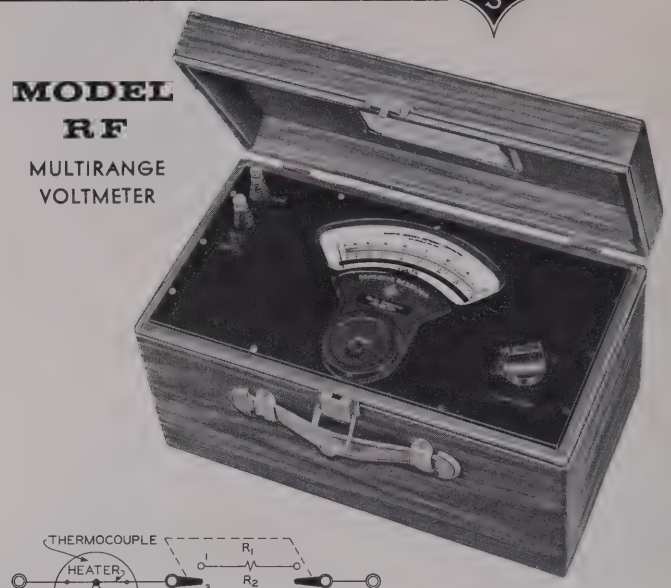
VOLTMETERS

Frequency: All Model RF voltmeters have a rated accuracy of .5% when used on DC and AC from 7 cps. Frequency influence is negligible over the first 20% of the entire frequency span for each range, and, therefore, no correction in direct reading accuracy need be made in that area. There is a frequency influence of no greater than .5% when usage is over the upper 80% of the frequency span. The maximum frequency at which each voltage range can be employed without exceeding .5% frequency influence is as follows:

Range (Volts)	Max. Freq. (Megacycles)	Range (Volts)	Max. Freq. (Megacycles)
1	5	20 & 30	.6
1.5-3	2	50 & 75	.4
5	1.5	100	.2
7.5 & 10	1	150-300	.15
15	.75		

RANGES

Range	Ω/v	Scale Div.	Code	Price
1/3/10/30/100/300	200	100/150	RFVOLT	$538.00
1/2/5/10/20/50	200	100	RFVATS	505.00
1.5/3/7.5/15/30/75	200	150	RFVEEK	505.00
5/10/20/50/100/200	200	100	RFVIOZ	513.00
7.5/15/30/75/150/300	200	150	RFVYOX	518.00



MODEL RF
MULTIRANGE VOLTMETER

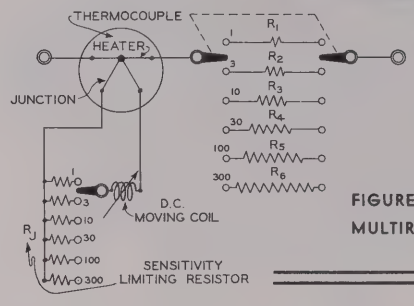
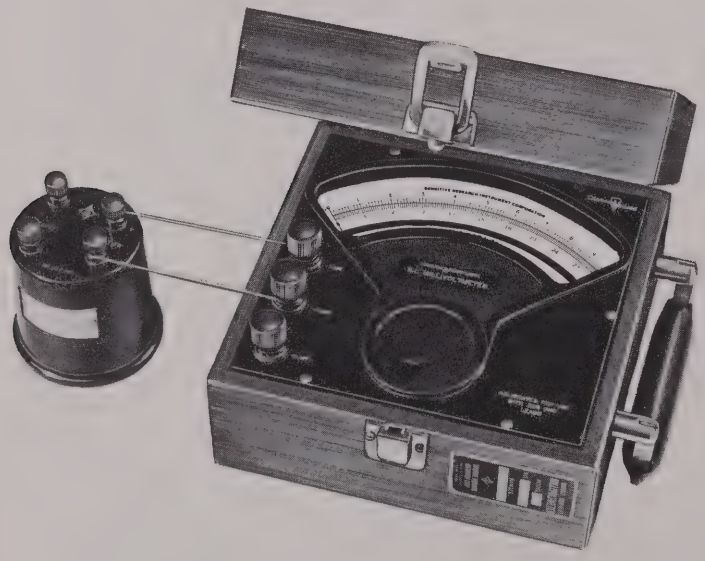


FIGURE 4. MODEL RF MULTIRANGE VOLTMETER CIRCUIT

RADIO FREQUENCY MEASUREMENTS

USING A DC MILLIVOLTMETER AND EXTERNAL THERMOCOUPLES



MODEL S DC MILLIVOLTMETER AND EXTERNAL MODEL T MOUNTED VACUUM THERMOCOUPLE

A DC millivoltmeter, with ranges from 2 to 10 mv full scale and a nominal sensitivity of 5 Ω/mv, can be used in conjunction with external instrument thermocouples to measure RF voltages and currents with true rms response.

The scale of the indicating instrument is drawn directly in DC millivolts and the characteristics of individual thermal elements are plotted against it to obtain a calibration curve in AC voltage or current. (See pg. 411, "Thermocouple Calibration Data.") The overall combination has a temperature coefficient of approximately .2%/C°. Current measurements are made by connecting the junction terminals of the thermocouple to the millivoltmeter and applying an input directly to the heater terminals. Voltage measurements are made by placing a resistance in series with one heater terminal and following the same procedure.

When selecting a millivoltmeter for use with thermocouples, the "open circuit" rating listed can often be misleading since this figure does not take into account the loading introduced by the instrument and the junction circuit of the thermocouple. This figure is valid only when recording by potentiometric methods or the equivalent. It can be proven mathematically that the most efficient operation occurs when the resistance of the millivoltmeter equals the resistance of the thermocouple junction circuit. Since the junction resistance of thermocouples varies from 5 to 15Ω, a 2 mv, 200 μa instrument having an internal resistance of 10Ω is generally considered to have optimum sensitivity. Rated current into such loading produces an output of approximately 3.5 mv. By operating the thermocouple at an overload of 50%, an output in the range of 7 to 8 mv can be generated. The user can either (1) apply series resistance to the junction circuit to limit the output of the thermocouple to match full scale on the millivoltmeter, or (2) obtain an instrument with ranges that can indicate the maximum emf generated from 0 to 150% of rated input to the thermocouple.

Listed below are recommended millivoltmeters, mounted vacuum thermocouples with insulated heater and junction circuits (see Figure 5) and, at right, heavy current air couples. For additional details on Model S millivoltmeters see Section 3.

MODEL S MILLIVOLTMETERS

Specifications: Accuracy .5% of full scale; 100 division, 6.3" hand-drawn mirrored scale; sensitivity 5 Ω/mv; shielded; diamond pivoted; formica case.

Range	Code	Price
2 mv	SMVPU	$195.00
5 mv	SMVSI	195.00
2/5 mv	SMVZO	215.00
*3/10 mv	SMVLA	245.00

*Constant resistance of 10 Ω (both ranges)

MODEL T INSULATED HEATER MOUNTED VACUUM THERMOCOUPLES

Frequency influence less than .5% from DC and 7 cps to 10 mc. Maximum allowable current is 200% of normal rating.

Normal Milliamps	Approx. Open Cir. Millivolts	Insulated Type Max. Heater Resistance	CASE MOUNTED Code	Price
1.0	7	2000	TEBPAP-S	$73.00
1.5	7	1000	TEBONY-S	63.00
2	7	800	TEMPIR-S	58.00
5	7	80	TELAMG-S	53.00
7	7	45	TEVERT-S	53.00
7.5	7	40	TEZZIN-S	53.00
10	7	20	TENORT-S	53.00
15	7	14	TELERT-S	53.00
20	7	10	TEKEST-S	53.00
25	7	7	TELFRO-S	53.00
50	7.5	5	TEBALT-S	53.00
100	7.5	2	TESOFT-S	53.00
150	7.5	1.5	TEMAID-S	53.00
250	7.5	.6	TECANT-S	53.00
500	7.5	.4	TESACT-S	53.00

Vacuum thermocouples of all types are listed separately in Section 10.

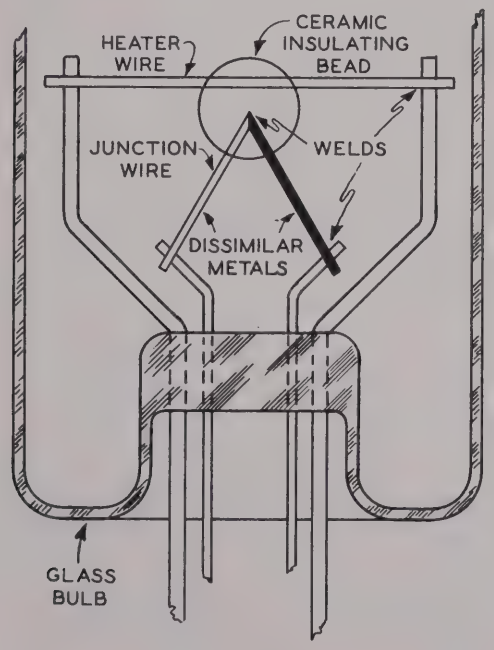


Figure 5. Insulated Heater Type Thermoelement

MODEL TX AIR THERMOCOUPLES

Frequency influence less than .5% from DC and 7 cps to 20 mc. Contact type junction circuit is used. Maximum allowable current is 150% of normal rating.

Normal Amps	Code	Price
1	TXARO	$53.00
2	TXEAM	53.00
5	TXILE	53.00
10	TXEZI	59.00
20	TXUBY	$70.00
30	TXOOG	78.00
50	TXOHR	100.00
100	TXAMP	225.00

MODEL TM

A multirange thermocouple unit for use with millivoltmeters. Frequency influence is less than .5% from DC and 7 cps to 100 kc. Unit consists of 5 individual vacuum thermocouples of the insulated junction type. The junction leads are switch controlled and connect to a single set of output terminals. Ranges listed below can be varied, if required, to suit the user's application.

Range	Code	Price
2/10/50/100/500 ma	THERUN	$210.00

Note: Calibration figures for each thermocouple range can be supplied as listed below.

THERMOCOUPLE CALIBRATION DATA

The output of any thermocouple can be plotted against the scale of a millivoltmeter. While it is advantageous to calibrate both units together, it is not necessary to return the millivoltmeter if additional thermocouples are ordered at a later date. Simply specify the serial number of the instrument and data can be supplied from a standard millivoltmeter of the same type.

Thermocouples can be supplied with 4 types of calibration data as follows:

Calibration No. 1: Adjusted with rated heater current for full scale on a particular single range millivoltmeter. (Includes junction resistance.) Customer must supply an instrument or exact specifications as to loading of the indicator with which the thermocouple is to be used.

Price $20.00 per thermocouple

Calibration No. 2: Calibrated for use with a particular double range millivoltmeter. If the output of the thermocouple at rated current exceeds the highest range of the millivoltmeter, a resistance is inserted in the junction circuit to limit the output to full scale deflection. Calibration data is furnished for both ranges.

Price $25.00 per thermocouple

Calibration No. 3: Calibrated by potentiometric methods. The "open circuit" emf of the thermocouple is measured when zero to rated current is applied.

Price $20.00 per thermocouple

Calibration No. 4: Same as No. 3 but thermocouple output is measured from zero to maximum allowable current.

Price $25.00 per thermocouple

UNIVERSITY MODEL COMPACT THERMOCOUPLE MILLIAMMETERS & VOLTMETERS

UNIVERSITY MODEL

SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.75% of full scale
FREQUENCY	DC and 7 cps to 7.5 kc max. (single range milliammeters for use up to .5 mc). Frequency specifications for individual instruments listed below.
TYPE	Thermocouple; permanent magnet, double pivoted moving coil; true rms response
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	6 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
TEMPERATURE COEFFICIENT	Approximately .2%/C°
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 5 5/16" x 5 1/8" x 3 1/8" deep; carrying handle
APPROX. WEIGHT	4 lbs. net; 8 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

Instruments with special scales and/or ranges available. Correspondence is required.

GENERAL DESCRIPTION

The University Model of the thermocouple type is an economically priced, compact, AC/DC indicating instrument for measurements in the medium audio frequency range. (Single range milliammeters have a relatively flat frequency response up to .5 mc.) It utilizes standard vacuum thermocouples. All instruments are diamond pivoted with shock mounted sapphire jewels to give a virtually friction-free moving element. Ranges are switch controlled for operating convenience.

Space limitations do not permit the installation of automatic temperature compensation, a thermocouple overload protection system, or a thermocouple replacement feature. However, uncalibrated thermocouples can be supplied for replacement in the field if desired. (See Section 10.) The user in such cases should have a facility for either re-drawing the original instrument scale to the characteristics of the new thermocouple or calibrating the thermocouple against the original scale and using the instrument with correction curves. (A precision instrument scale drawing machine is described in Section 9.)

The University Model is also offered as a (1) AC/DC dynamometer instrument (see section 4), (2) AC/DC wattmeter (see section 5), (3) DC permanent magnet moving coil instrument (see section 3), and (4) AC/DC electrostatic voltmeter (see section 6).

OPTIONAL ACCESSORIES

Voltage ranges can be extended by the addition of external multipliers. Frequency range must be specified. If multipliers are ordered with the instrument, both units can be calibrated together and overall accuracy is within the accuracy of the instrument. (Multipliers are described in Section 10.)

MILLIAMMETERS

Frequency: a) Single range instruments; DC and 7 cps to .5 mc at .75% accuracy.
b) Multirange instruments; DC and 7 cps to 7.5 kc at .75% accuracy.

Single range instruments can be supplied from 2 ma to 500 ma full scale. Ranges and resistances same as for the Model RF listed on page 408. Order by specifying the University Model and the range required. Deduct $85.00 from the price of the single range Model RF for the price of the University Model.

Range	Approx. Resist. Ω	Scale Div.	Code	Price
2/10/20/100/200	640/538/295/63/32	100	UTHEMO	$263.00
5/10/50/100/500	70/205/74/37/7.5	100	UTHENY	245.00
10/20/100/200/1000	30/37.5/12/5.8/1.2	100	UTHEOS	245.00
10/50/100/500/1000	30/21/12/2.4/1.2	100	UTHEPO	245.00
20/100/200/500/1000	10/3.6/2/.8/.4	100	UTHEIK	245.00

VOLTMETERS

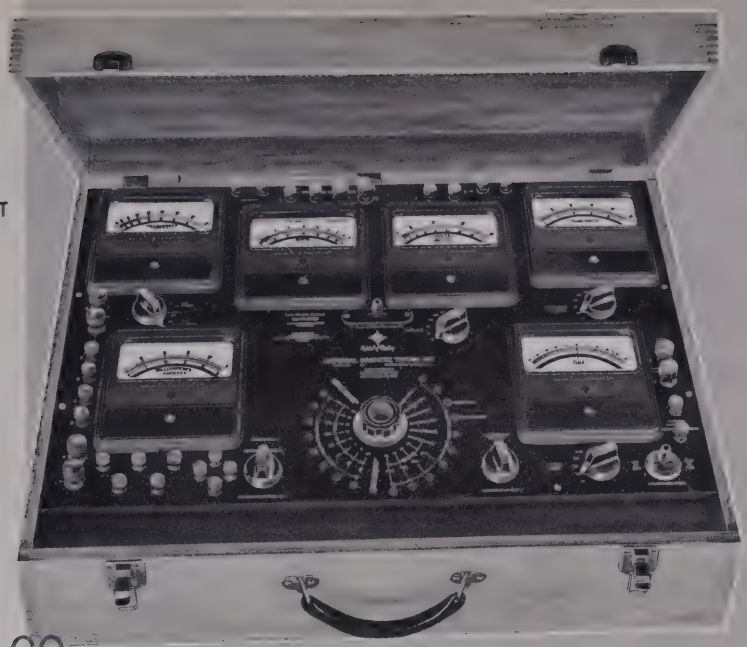
Frequency: a) Instruments with a sensitivity of 500 Ω/v; DC and 7 cps to 4 kc at .75% accuracy. In multirange instruments, ranges of 300 v or higher, rated accuracy to 2 kc; 1.5% accuracy above 2 kc to 4 kc (single range instruments 1% accuracy).
b) Instruments with a sensitivity of 100 Ω/v; DC and 7 cps to 6 kc at .75% accuracy. In multirange instruments, ranges of 300 v or higher, rated accuracy to 4 kc; 1.5% accuracy above 4 kc to 6 kc (single range instruments 1% accuracy).

Any single range instrument with a sensitivity of 100 Ω/v, from .2 v to 300 v full scale, price $226.00; over 300 v to 1000 v, price $245.00. When sensitivity is 500 Ω/v, ranges from 1.5 to 300 v, price $256.00; over 300 v to 1000 v, price $275.00.

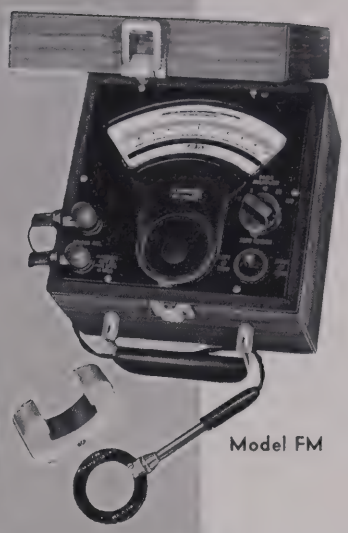
When ordering, specify model, range and ohms per volt required.

Range	Scale Div.	Code	Price 100 Ω/v	Price 500 Ω/v
.2/1/5/10/20	100	UTHOCI	$256.00	—
3/15/30/75/150	60/75	UTHOXI	256.00	$296.00
7.5/15/30/75/150	75/60	UTHOPP	256.00	296.00
15/30/75/150/300	75/60	UTHONS	261.00	301.00
1.5/3/7.5/15/30/75/150	75/60	UTHODO	280.00	325.00
7.5/15/30/75/150/300	75/60	UTHORA	273.00	315.00

Prices and Specifications Subject to Change Without Notice
Printed in U.S.A. 75-1



Model MAT



Model FM

STERLING CO.
Manufacturers' Representatives
300 SOUTH DIXIE DR.
DAYTON 39, OHIO
AX 8-7573

Portable and Panel

MAGNETIC TESTING INSTRUMENTS

FLUXMETERS, FLUXMETER CALIBRATOR, FLUX VOLTMETERS

UNIVERSAL MAGNETIC TESTING SET ● AC CORE LOSS TEST SET

Model	Description	Page
FS	.5% Single Range DC Fluxmeters. 5.2" scale length	452-454
FM	.5% Multirange DC Fluxmeter. 5.2" scale length	452-454
GPS	General Purpose Search Coil	452
STM	Standard Magnet	452
FCM	Special Magnet and Search Coil to calibrate fluxmeters	452
FC	Fluxmeter Calibrator for use as a fast, precision laboratory standard	455
FLV	.5% AC Flux Voltmeters. 6.3" scale length	456
FLVC	.25% AC Flux Voltmeters. 6.3" scale length	456
	A Discussion of Commercial Magnetic Measurements	457-458
MAT	Universal Magnetic Testing Set	459-461
EPS	Standard 25 cm Epstein Frame for core loss testing	461
MU	Mutual Inductors for AC permeability testing	461
COL	AC Core Loss Test Set	462

Prices and specifications subject to change without notice. *Terms net 30 days F.O.B. New Rochelle, N.Y.*

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

Electrical Measuring Instruments Since 1927

MODELS FS and FM DC FLUXMETERS

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	1% of full scale.*
SENSITIVITY	10,000 lines per division using a 1 turn search coil
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
SCALE DIVISIONS	100 divisions printed 50-0-50 (Zero Center)
POINTER	Knife edge
DAMPING	Induced emf
PIVOTS	Polished osmium alloy point, non-magnetic shaft
JEWELS	Sapphire
SHIELDING	Electrostatic
RANGE CHANGING	Model FM switch controlled
MECHANICAL ZERO	Lever switch and internal battery
CASE	Formica; 7¾" x 7½" x 6⅛" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	6 lbs. net; 22 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

*Full scale in a "Zero Center" instrument is defined as the sum of the full scale deflections to either side of zero.

OPTIONAL SPECIFICATIONS

1. Instruments can be supplied at no extra charge with "Zero Left" rather than "Zero Center" scales. Other special scales can be furnished if required but correspondence is necessary.

OPTIONAL ACCESSORIES

1. A 10 turn, 15 ohm general purpose search coil with a mean area of 15 square cms and a 1¼" center hole is available and recommended for use with the models FS and FM. It has a 5" metal handle and 3' flexible test leads. **Specify: Model GPS. Price $40.00.**

Information is available on the design of special search coils. Because of the wide variety of requirements encountered in various applications only a standard search coil can be supplied by Sensitive Research.

To achieve maximum absolute accuracy, special search coils must always be made up to 15 ohms. Where extreme sensitivities are required purely on a comparative basis, such as checking residual magnetism on small samples of soft steel, search coil resistances of much more than 15 ohms can be used on the X1 range of the Model FM or with the most sensitive Model FS. Under these conditions, multiplier values and calibrations are incorrect, but accurate comparisons can be made. (See Fig. 1.)

2. Standard "U" shaped magnets adjusted to an accuracy of 1% are available with any fixed value of total flux from 10,000 to 50,000 lines (maxwells). **Specify:** Model STM and give value of total flux desired. **Price $40.00.**

MODEL FM and Search Coil

3. A general purpose 10 turn search coil and a 50,000 line standard magnet can be supplied as an inexpensive .5% accurate system for calibrating fluxmeters. This combination can check full scale deflection (on either side of zero) for the Model FM multirange fluxmeter, on its X1 range; and for a Model FS single range fluxmeter, with a range of 500,000 lines. Additional magnets are available with any value from 10,000 lines to 50,000 lines and can be calibrated with the search coil to provide .5% accurate checks at intermediate scale points. For the search coil and 50,000 line magnet, specify the **Model FCM. Price $105.00.** If additional magnets calibrated with the search coil are desired, specify the values required in lines or maxwells. **Price $65.00 each additional calibrated magnet.**

The attention of the user is directed also to the Model FC, a fluxmeter calibrator developed for production testing of the models FM and FS at Sensitive Research. See Pg. 455.

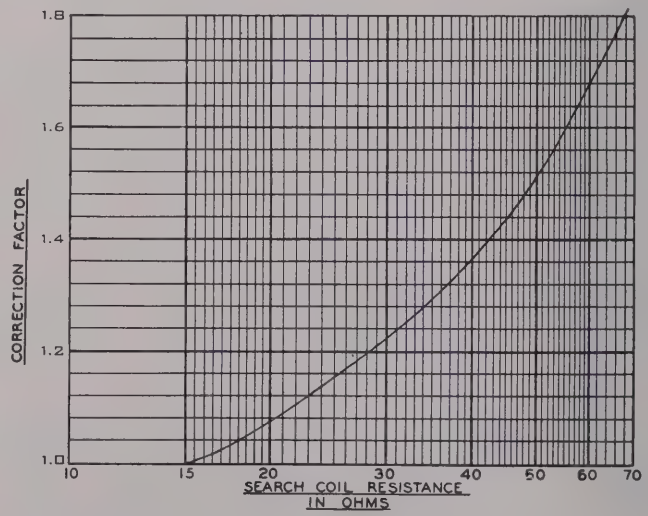


Figure 1.

Approximate correction curve for use with search coils over 15 ohms. (Applies to fluxmeters manufactured after Nov. 1958.)

GENERAL DESCRIPTION

The Models FS (single range) and FM (multirange) are direct reading fluxmeters for the measurement of total magnetic flux in maxwells (or cgs lines) and use in related applications such as (1) *obtaining B-H curves,* (2) *DC permeability testing,* (3) *determining the number of turns wound on an iron core or that can be placed on an iron core* and (4) *measurements of electrical discharge.* By calculation, if the area of the search coil is known, readings in lines (or cgs lines or maxwells) can be converted to indicate flux density in lines per square cm, or gausses. The only difference between the two models offered is that the Model FM is supplied with 5 switch controlled ranges while the Model FS is a single range instrument only.

The fluxmeter is actually a galvanometer movement without restraining springs. Deflection of the pointer is opposed only by a counter emf set up by the rotation of the moving coil in a magnetic field. The pointer remains at its maximum deflection unless manually actuated by the user to return to zero. A lever switch is mounted on the panel for this purpose. Power is supplied by an internal mercury battery. If desired, at slightly reduced accuracy, the range of the instrument can be increased twofold by zeroing the pointer at full scale instead of center scale.

The fluxmeter has many advantages over the ballistic galvanometer method of making magnetic measurements. When using the latter instrument, it is essential that the discharge from the search coil be completed before the galvanometer coil begins to move and the deflection of the galvanometer must be quickly observed "on the run" before it returns to zero. In the fluxmeter, because it lacks an appreciable restoring torque, deflection is virtually independent of the insertion speed of the search coil, and the pointer remains with little drift for short periods of time at its maximum deflection.

The fundamental sensitivity of the fluxmeter is 10,000 lines per division using a 1 turn 15Ω search coil. Sensitivity can be increased on a pro rata basis by using a search coil with more turns. As an example, a search coil of 100 turns enables a sensitivity of 100 lines per division; 1000 turns, 10 lines per division, and so on in similar sequence. To achieve maximum accuracy, however, the search coil must be made up to 15Ω as accurately as possible. Search coils can be used with resistances that exceed 15Ω, but at reduced accuracy. This applies only to the X1 range of the Model FM or a 500,000 line Model FS. (See Fig. 1.)

The relatively complex theory of operation of the models FM and FS fluxmeters can be rather simply explained. An external search coil encloses a definite number of flux lines with a definite number of turns. An internal coil of a number of turns encloses a definite number of lines created by an internal permanent magnet. From the conservation of energy theory, it requires energy to change the flux linkages of this complete circuit, but because of the absence of springs or friction, no latent energy is present. Therefore, when the external flux changes the number of lines linking the search coil, the internal coil, if it is not to have energy expended, takes up a position such that it cuts more or fewer lines (as the case may be). The final position of the pointer is achieved when the total lines being enclosed by the whole circuit, internal and external, is the same as originally existed.

While the fluxmeter design presupposes a theoretically torqueless moving system, actually some small restraining forces do exist. These do not appreciably affect accuracy or operation. When the fluxmeter is used with a 15Ω search coil, mechanical positioning is guaranteed to a stability of ±1 division for 15 seconds.

Applications of the Models FS and FM

Fluxmeters of this design can be employed in innumerable applications requiring general DC magnetic measurements or integration. A brief résumé of some of the most common usages is given in the following discussion.

(1) Measurements of Magnetic Flux in Maxwells and Gausses

A search coil of known number of turns and mean area in square cms is inserted into a magnetic field to be measured. It is removed from the field to a position of zero flux. The fluxmeter scale reads directly in cgs lines as follows:

A. Total flux in cgs lines $= \frac{KD}{T}$

where K = cgs lines per division for a specific fluxmeter and range used
D = divisions deflection
T = number of turns in search coil

If the reading equals 20 divisions when used on the X1 range of a Model FM fluxmeter with a 10 turn 15Ω search coil, then:

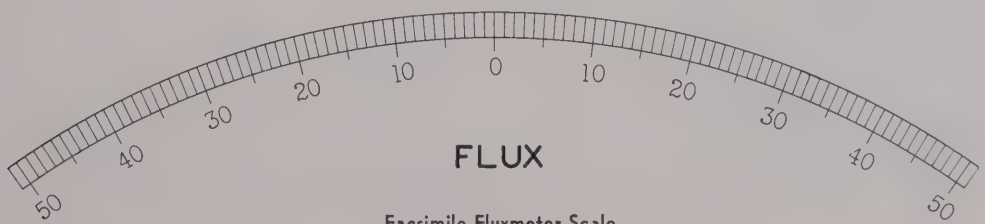
$$\text{Total flux} = \frac{KD}{T} = \frac{10{,}000 \times 20}{10} = 20{,}000 \text{ cgs lines}$$

B. To find the strength of a magnetic field in cgs lines per square cm, or gausses

$$\frac{\text{cgs lines}}{\text{area}} = \frac{KD}{TA} = \text{gausses where A} = \text{mean area of search coil in square cms}$$

(2) Obtaining β-H Curves

The sample to be tested should preferably be in a toroidal core form having a primary and a secondary winding. Its radial thickness should be made small as compared with its mean radius. By connecting (1), the primary winding (through a reversing switch) and an ammeter to a DC supply, and (2), the secondary winding to a fluxmeter, points for a β-H curve can be obtained by quickly reversing the current and reading the fluxmeter deflection.



Facsimile Fluxmeter Scale

The magnetizing field is easily determined from the current in the magnetizing winding and the magnetic path length.

Magnetizing force in oersteds (gilberts per cm) $= H = \frac{.4\pi NI}{L}$ where

N = Number of turns in primary winding; I = Primary current in amperes; L = Mean length of magnetic path in cm $= 2\pi r$ where r is the mean radius of the ring in cm:

Flux density in maxwells per square cm or gausses $= \beta = \frac{DK}{2ANs}$ where

D = Fluxmeter deflection; K = Maxwells per division (fluxmeter sensitivity); A = Cross sectional area of magnetic path is sq. cm; Ns = Number of turns in secondary winding; 2 = Constant because current is reversed and flux density changes from $+\beta$ to $-\beta$.

(3) DC Permeability Testing

Such measurements are made by using data obtained from B-H curves.

$$\text{Permeability} = \frac{\beta}{H} = \frac{\text{gausses}}{\text{oersteds (gilberts per cm)}}$$

(4) Determining the Number of Turns in an Unknown Coil Wound on an Iron Core or That Can Be Placed on an Iron Core

This is accomplished by winding a few turns along the length of an unknown coil and connecting to a fluxmeter. A measured current is reversed through the unknown coil and the deflection on the fluxmeter noted. An exact number of turns is wound over both the unknown coil and the search coil, and a current is reversed through this coil to produce the same fluxmeter deflection. (See Fig. 2.) Then:

$$\text{Unknown turns} = \frac{\text{ampere turns in substitute winding}}{\text{amperes in unknown winding}}$$

NOTE: If the coil to be checked is not on a ferromagnetic core, it must be placed temporarily on some form of closed magnetic path.

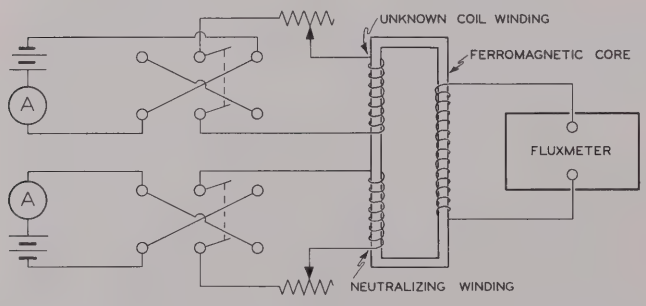


Figure 2

(5) Measurement of Electrical Discharges

In this application the fluxmeter can be considered a calibrated coulomb meter. The discharge must take place through a low resistance, non-inductive shunt. Then:

Coulombs discharged $= (Q) = \frac{DK}{R \times 10^8}$ where D = Fluxmeter deflection; K = Maxwells per division of fluxmeter; R = Resistance of shunt in ohms.

Milliampere seconds discharged $= \frac{DK}{R \times 10^5}$

PANEL MOUNTED INSTRUMENTS

The models FS and FM are also available for vertical panel mounting in the shallow EW-5A (5″ scale length) or EW-7A (7″ scale length) edgewise panel case. (For dimensions see page 220, Section 3.)

Performance characteristics are the same as listed for the portable type except that the lever switch and battery employed to zero the movement are furnished separately for installation in the user's panel.

Specify: A. *Single Range:* Model FSEW-5A or FSEW-7A and code word of single range fluxmeter having range desired. Price $265.00.

B. *Multirange:* Model FMEW-5A or FMEW-7A, Code FLUXO. Price $360.00.

NOTE: For production testing, an edgewise panel mounted fluxmeter can be furnished with a "zero left" scale and arranged so that the user can provide continuous automatic return of the pointer to zero. This requires an external battery and a switch that is either foot operated or incorporated into a test jig. Such operation allows for high speed semi-automatic testing of magnets. Correspondence is suggested.

If the application makes it desirable, fluxmeters can be supplied in a flanged case for recessed mounting in a horizontal bench. Terminals can be placed either on the top panel or on the underside of the case. Specify "Flanged case for bench mounting" and add $15.00 to the price of the portable model.

RANGES

Ranges and sensitivities listed below are based on using the fluxmeter with a 1 turn search coil. If a standard Sensitive Research general purpose 10 turn search coil is used, sensitivity is increased by a factor of 10. Full scale range is on the basis of a "zero center" scale. By zeroing at full scale, twice the normal full scale deflection can be obtained.

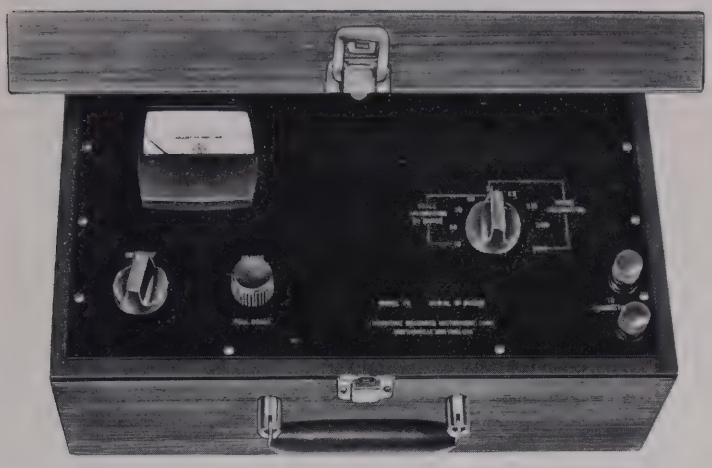
MODEL FS (Single Range)

Full Scale Range in Lines	Sensitivity in Lines/Div.	Code	Price
500,000	10,000	FLUXA	$225.00
1,500,000	30,000	FLUXE	225.00
5,000,000	100,000	FLUXI	225.00
15,000,000	300,000	FLUXU	225.00
50,000,000	1,000,000	FLUXY	225.00

MODEL FM (Multirange)

Full Scale Range in Lines	Switch Position	Sensitivity in Lines/Div.	Code	Price
500,000	X1	10,000	FLUXO	$320.00
1,500,000	X3	30,000		
5,000,000	X10	100,000		
15,000,000	X30	300,000		
50,000,000	X100	1,000,000		

MODEL FC



SPECIFICATIONS

PORTABLE DC FLUXMETER CALIBRATOR

ACCURACY	.2% of output
OUTPUT RANGES	Specific calibration points as follows: 100,000 / 200,000 / 300,000 / 400,000 / 500,000/1.5 million/5 million/15 million/ 50 million flux linkages. (Output ranges correspond to cardinal points on the Model FM multirange fluxmeter scale as follows: 10/20/30/40/50 on either side of zero on the X1 range and full scale for all other ranges.)
RANGE CHANGING	Switch controlled
OUTPUT RESISTANCE	15Ω
TEMPERATURE COEFFICIENT	.04%/°C for a deviation of ±5°C from a reference temperature of 25°C
POWER REQUIREMENTS	2 # RM-42R Mallory batteries (or equal) mounted internally and replaceable from the back of the case.
CASE	Formica; 13¾" x 7½" x 6½"; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	12 lbs. net; 26 lbs. shipping

OPTIONAL SPECIFICATIONS

1. Special output ranges having a value of any multiple of 100,000 flux linkages and not exceeding 50 million flux linkages can be supplied. Standard output ranges (as listed above) up to and including 5 million flux linkages can be furnished for use with instruments requiring an external circuit resistance of 1Ω or less in addition to the normal 15Ω specified. Correspondence is invited.

PANEL MOUNTING

The Model FC can be supplied on a standard 19" x 7" x ⅛" grey aluminum panel for rack mounting.

Specify: Model FC-P Code FLUCAL **Price:** $457.00

GENERAL DESCRIPTION

The Model FC provides .2% accurate calibration points for checking the Sensitive Research Models FM and FS fluxmeters (see pages 452-454), or any other fluxmeter or ballistic galvanometer designed for use with a 15Ω external circuit. It is a simple to operate, easy to maintain, rapid calibrator, with higher accuracy than it has hitherto been possible to furnish in a low cost instrument. When calibrating the multirange Model FM, it provides a check for basic scale linearity at 10 points (5 points on either side of "0") as well as for all ranges at full scale. Consequently it is ideally suited for the calibration of this instrument and the Model FS with a range of 500,000 lines full scale.

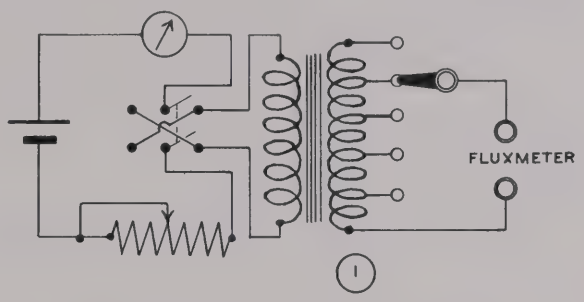


Fig. 1. Basic circuit of fluxmeter calibrator.

The calibrator is furnished complete and requires no accessory equipment or standards. Operation of the instrument is based on the complete flux reversal of a "square loop" core material driven well into saturation. (See Fig. 1.) The core has two windings—a primary for the exciting current, and a secondary with taps to adjust to an appropriate number of turns to sense the flux reversals in the core. These flux reversals constitute the calibration energy for the fluxmeter. In such usage saturation density is an extremely stable characteristic and repeatability and long term stability are readily achieved. The exciting current, which only slightly affects total flux density and hence does not have to be accurately controlled, is set by adjusting a rheostat to give full scale deflection on a 2½" scale panel meter.

Recommended batteries are the Mallory RM-42R or equivalent. They can be expected to have a 100 hour life when in continuous usage and at least twice this figure when the calibrator is used intermittently.

Model FC Code FLUCAL **Price: $342.00**

Calibrating a Model FM Fluxmeter

MODELS FLV and FLVC
FLUX VOLTMETERS

SPECIFICATIONS

AC PORTABLES—HORIZONTAL USE

ACCURACY	A. Model FLV: .5% of full scale B. Model FLVC: .25% of full scale
FREQUENCY	A. Model FLV: 25 cps to 1000 cps B. Model FLVC: 25 cps to 500 cps
TYPE	Full wave rectified, permanent magnet, double pivoted moving coil. Responds to the average value of a voltage.
SENSITIVITY	A. Model FLV: 1000 Ω/v or 3333 Ω/v as indicated B. Model FLVC: 1000 Ω/v
SCALE	Hand-drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	1-2 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Magnetic; electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; ±3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7¾" x 7½" x 4⅝"; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	7 lbs. net; 10 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

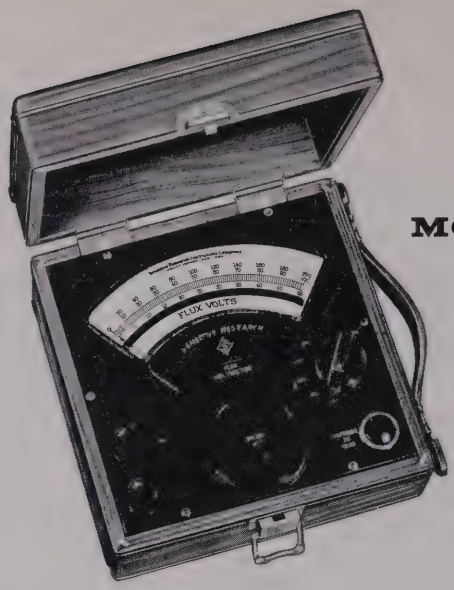
1. Special ranges and/or scales are available. Ranges starting from 5 v full scale can be supplied in the Model FLV, and from 15 v full scale in the Model FLVC. Lower range instruments down to 1 v full scale are available in the Model FLV but they have large and non-linear temperature coefficients, varying in the area of 0.3%/C°, and therefore are practical only for usage in a closely controlled laboratory environment. The number of ranges that can be supplied in a multirange instrument depends on the accuracy required and their full scale values. In general, separate scales must be drawn in the Model FLV for all ranges of 50 v or less, and in the Model FLVC, for all ranges of 100 v or less. Correspondence is required.

PANEL MOUNTED INSTRUMENTS

The Models FLV and FLVC are available for vertical panel mounting in the shallow EW-5A (5" scale length) and EW-7A (7" scale length) edgewise panel cases. (For dimensions see page 220 of Section 3.) Performance characteristics are the same as listed for the portable types excepting the EW-5A case can accommodate a maximum of 100 scale divisions.

Ordering Information: Designate the portable model desired and add the suffix EW-5A or EW-7A. (Example: Model FLVEW-5A.) Specify the code word for the ranges desired, and when ordering the Model FLV, whether sensitivity is to be 1000 Ω/v or 3333 Ω/v.

Price: Add $25.00 to price listed for the code word of the instrument selected.



MODEL FLV

GENERAL DESCRIPTION

The Models FLV and FLVC are full wave rectified, average reading AC voltmeters calibrated in terms of the rms values of a sine wave (average volts × 1.111). Their designation as "flux voltmeters" arises from the fact that instruments of this type have been widely employed in magnetic measurements to ascertain the maximum flux density (β) of transformer windings. They are extremely useful in this application because the flux density induced in a magnetic core is proportional to the average value of both the positive and negative half cycles of the voltage. Since the flux voltmeter only responds to average values, variations in waveform do not cause errors in the instruments' response to flux density. In flux density measurements near saturation, the accuracy of the flux voltmeter is of importance because errors of setting flux density are reflected as much larger errors in core loss and exciting va readings. It is for this reason that accuracies of both .5% and .25% are offered. The reader is referred to the American Society for Testing Materials' publication "Standard Methods of Test for Alternating Current Core Loss and Permeability of Magnetic Materials" (ASTM Designation: A343) for a complete description of the application of flux voltmeters in magnetic measurements.

The Models FLV and FLVC can also be employed as general purpose AC voltmeters when usage is on a sinusoidal waveform. In only this instance do the scales read true rms values. They make excellent indicators that are somewhat preferable to other AC types because of a combination of qualities which include fast response time, high sensitivity, wide frequency range and overall general ruggedness.

		MODEL FLV†			MODEL FLVC	
			Price		Price	
Range	Scale Div.*	Code	1000 Ω/v	3333 Ω/v	Code	1000 Ω/v
30/75	150	FVABO	$250.00	$270.00	FVABOC	$325.00
60/120	120	FVDEF	255.00	275.00	FVDEFC	330.00
75/150	150	FVGOI	255.00	275.00	FVGOIC	330.00
5/10/20	100	FVVUL	370.00	390.00	—	—
7.5/15/30	150	FVVEE	350.00	370.00	—	—
7.5/15/150	150	FVVAK	350.00	370.00	—	—
30/75/150	150	FVJOL	275.00	295.00	FVJOLC	350.00
50/100/200	100	FVANO	283.00	303.00	FVANOC	358.00
75/150/300	150	FVPOR	283.00	303.00	FVPORC	358.00
30/75/150/300	150	FVVOX	307.00	327.00	FVVOXC	382.00

** According to number of ranges and model, individual instruments have up to 4 sets of scale divisions.*

† Specify Ω/v required when ordering.

COMMERCIAL MAGNETIC MEASUREMENTS

Organizations performing magnetic measurements are consistently plagued by test results that exhibit less than satisfactory overall accuracy and precision. There often exists not only a lack of agreement between producers and users of magnetic materials employing the same test procedures on the same materials, but also significant discrepancies within an organization trying to repeat its own results. The basis of this discussion is to examine carefully some of the major problems encountered in magnetic measurements and to relate their solution to the extensive line of Sensitive Research test equipment designed specifically for this application. In particular this analysis is meant to serve as a preface to the specifications for the **Model MAT, Universal Magnetic Testing Set** (see pages 459-461) and the **Model COL, Core Loss Test Set** (see page 462).

The greatest volume and hence the greatest measurement needs occur in the "soft" magnetic steel industry. "Soft" in this case refers to low retentivity materials such as low carbon and silicon steels, usually used in laminated form, primarily for transformers and motors. These materials can be classified as to whether they are high density or low density types and as to their use.

High density materials are those used for power transformers and motors. Such material is commonly sold on the basis of a va and/or watts per pound specification. Usual test densities are 10 kilogausses and 15 kilogausses. Tests are made using the circuit shown in Fig. 1.

In choosing the instruments for these tests, care must be exercised. The current instrument and the wattmeter field circuit are in series with the exciting winding of the test sample. These instruments must be of relatively low impedance or they have a major effect on the accuracy of the measurement being performed. The core material at these densities is extremely non-linear in response and it is impossible to maintain a sinusoidal waveform for both current and voltage. Therefore, it is desirable to keep the flux (induced voltage) sinusoidal, as high frequency components of a distorted wave have high loss factors and contribute more to high core loss readings than does a sinusoidal test. If series resistance is added in the exciting winding it tends to cause the current to be sinusoidal and the induced voltage becomes non-sinusoidal. Series resistance to adjust the excitation current cannot be used satisfactorily. This measurement requires not only low impedance instruments but a low impedance power source.

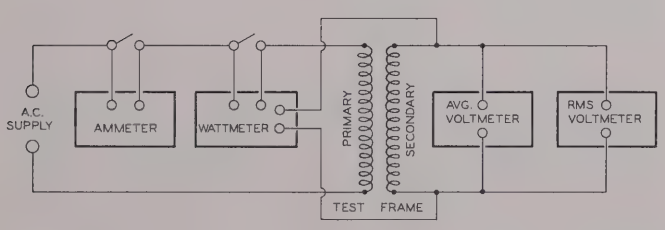


Figure 1.

The induced voltage is read on an average responding instrument whose scale is marked in terms of 1.11 × E average. Such an instrument is commonly called a "flux voltmeter" and it gives readings proportional to B max, regardless of waveform distortion. In addition, an rms responding instrument, as shown in Fig. 1, is in parallel with the flux voltmeter. These two instruments agree exactly (within their accuracies) for induced sinusoidal voltages, and when differences occur, these differences are indicative of the distortion present. This arrangement allows for a correct measurement of exciting va and core loss. The test sample can be in the form of a stack of 3 cm x 28 cm strips in an Epstein Frame. With care to keep copper losses negligible, it can also be two windings on a suitable stack of EI laminations. In some cases the sample material can even be used with a single coil and the potential circuits of the instruments connected directly across the exciting winding. *Great care must be used to minimize copper loss errors in single coil tests.*

The Circuit of Fig. 1 can be modified as shown in Fig. 2. Here an air core mutual inductor has its primary inserted in the exciting winding and provision for connecting the flux voltmeter to the secondary. The average voltage on the secondary is proportional to the peak of the exciting current. Using a calibration factor supplied with each mutual inductor, the peak exciting current can be determined. This peak exciting current is used to calculate an H max value, and combined with the B max value set by means of the flux voltmeter on the induced voltage winding on the test sample, it is used to determine permeability as being $\frac{B\ max}{H\ max}$. This is the value of permeability most often used for high and medium density materials. There are many other values of AC permeability which can be defined. This $\frac{B\ max}{H\ max}$ value is the value specified in ASTM Specification A343, and in lieu of any statement to the contrary is usually meant when discussing permeability in medium to high density tests.

A precaution must be observed in high density measurements to carefully define what is meant by path length and cross section of the sample material. ASTM specifications base all cross section values on sample weights and on assumed density for the material rather than on measured cross sections. Path length assumptions on EI samples can cause major discrepancies between different laboratories making similar tests.

Another factor that must be taken into consideration is the lack of reproducibility of the average sample of laminated materials. With samples .014" and thinner, in most commercial materials a test can be made, the material removed from the test fixture, shuffled and restacked in the same fixture, and a different set of readings obtained. Reasonable variations are in the order of ½% to 1½% for 10 kilogausses tests on Epstein samples and 1% to 2% for EI samples. For 15 kilogausses tests, these vary appreciably, approximating 1% to 2% for Epstein Frame samples and 1½% to 3% for EI samples. Correlation of results can not in general be relied upon to better than these values except on a statistical basis. These values are the variations due to the samples alone and do not include instrument errors.

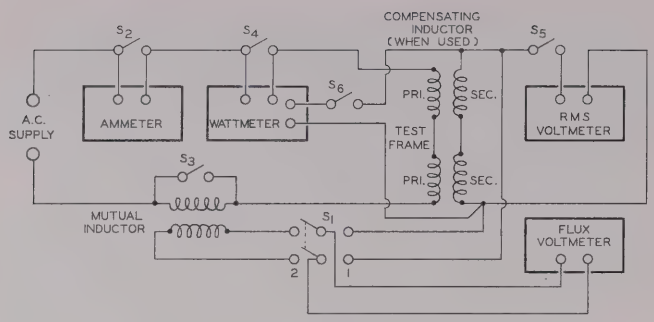


Figure 2.

In addition to high density core loss characteristics, many "soft" materials are also purchased on the basis of a low density specification. These materials are generally classed as audio grades. Common test densities are 40, 200 and 2000 gausses. At these densities the quality criterion is ordinarily permeability, which in this instance is usually defined as that value which when inserted into the formula $L = \frac{.4\pi N^2 \mu A}{10^8 l}$ gives the parallel inductance in henries. This value is obtained from either a bridge measurement or by impedance matching in some other comparison circuit. At the densities involved no particular problems with wave form are usually encountered. The ASTM method can be employed at medium densities and gives nearly comparable values of AC permeability. It is not suitable for very low density measurements, and at high density it does not give permeability values that agree with results obtained by bridge tests, nor do either of them agree exactly with values calculated from va measurements.

The second largest group of magnetic measurements are concerned with the "hard" magnetic materials used as permanent magnets. Various permeameter methods are used for research and design work with such materials. However, commercial users of hard materials are nearly always concerned with either total flux or "flux density in a gap" measurements. Total flux measurements are ordinarily made by insertion of a magnet into a coil and measurement of the change of flux linkages when it is removed. A fluxmeter or a ballistic galvanometer is most commonly used as the measuring instrument. Of the two, the fluxmeter is the more convenient and stable device. It eliminates the nuisance of taking readings "on the run" (see Model FM pages 452-454). For readings of gap density one can use either a suitably shaped search coil and a fluxmeter (or a ballistic galvanometer), or one of the Hall effect probes in small areas too tight to allow insertion of a satisfactory search coil. In some special cases a rotating coil can be inserted into a field as a pick up device and its output read as either an AC voltage or synchronously rectified and read as a DC voltage.

Many other types of magnetic materials are of course used commercially. Common are the ferrites and powdered iron materials for high frequency uses. Ferrites and tape wound core materials for "square loop" applications, and a whole field of special materials used for shielding purposes, require special tests related to their normal uses and do not readily fit into a general purpose measurements program employing standard procedures and instruments.

The entire previous discussion has been based on performing AC measurements on "soft" materials and DC flux measurements on hard materials. It should be noted that DC tests can be made also on all soft materials by merely using an excitation winding with DC flowing, and a sensing winding with a fluxmeter. Point by point measurements can then be made to trace out complete hysteresis loops. These DC tests are valuable as an investigative tool because they show the characteristics of a material without modification by other factors as is sometimes a problem in AC testing. In AC measurements the characteristics of a material are affected by gauge, insulation, burr and other similar frequency sensitive factors.

The Model MAT is the equivalent, with its available accessory equipment, of a complete magnetic testing laboratory. It is capable of all of the core loss, permeability and va measurements called for by ASTM, plus the DC measurements on both "soft" and "hard" materials. In addition it has built-in compensation circuits which eliminate errors from instrument losses and allow completely "tare free" readings of all values. (See pages 459-461.)

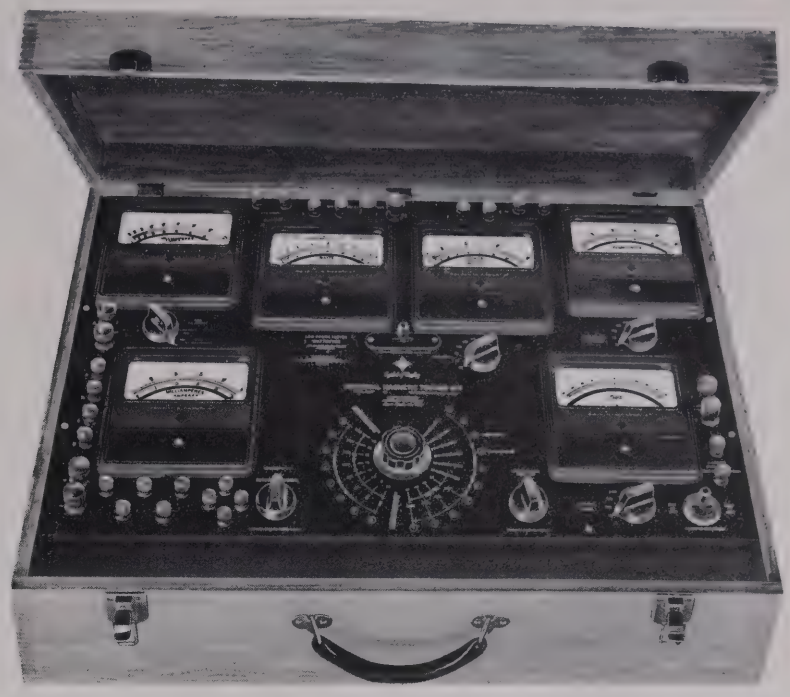
The Model COL makes the core loss and va measurements described in ASTM procedures and has a long scale flux voltmeter for extra resolution in setting flux density. This is of importance inasmuch as inaccuracies in setting density (the test voltage) produce errors that are much larger in core loss. The error in the exciting current at 15 kilogausses caused by the voltage error may be 10 to 20 times as large as the voltage error. The Model COL also has internal tare compensation. Primarily, it is a production type test set, whose specific purpose is to speed up and simplify core loss measurements, while providing more accuracy and resolution than available in the Model MAT in this one application. (See page 462.)

The exact range of sample size and measurements which can be made are so interlocked that they are hard to define separately. One must use a sufficiently large sample in order to read on the wattmeter the expected loss at the test density desired. In designing coils for tests on other than Epstein samples the same sensitivity limitations apply. There must be sufficient turns to allow the induced voltage to be within the range of the flux and rms voltmeters. Similarly, the exciting winding must operate within the range of the current meter for the turns used. In the case where the exciting winding and the induced voltage winding are not identical in turns, the measurement requires correction by an appropriate factor.

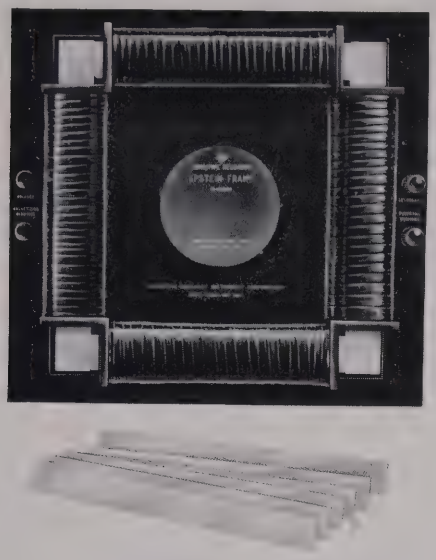
The purpose of the preceding discussion has been to describe briefly the most common procedures and problems associated with commercial magnetic testing. The subject is complex enough to prohibit complete coverage of the topic in this catalog. However, in most instances, the procedures detailed represent the area of total interest to industrial users and producers of commercial magnetic materials. For further information the reader is referred to the "Book of ASTM Standards" and the bibliographies listed therein.

MODEL MAT MAGNETIC TESTING SET
MODEL EPS EPSTEIN FRAME

MODEL MAT



MODEL EPS (EPSTEIN FRAME)



GENERAL DESCRIPTION

The Model MAT is a portable, multipurpose, magnetic testing set, designed for the following applications:

A. Measurements of core loss, va and permeability in accordance with the procedures of the American Society for Testing Materials (ASTM) as detailed in their publication "Standard Methods of Test for Alternating Current Core Loss and Permeability of Magnetic Materials" (ASTM Designation: A343).

B. A comprehensive DC analysis of hard and soft magnetic materials.

The test set was first introduced in 1954, and since that time it has been universally accepted by both producers and users of soft magnetic materials and hard magnets as the industry standard for core loss measurements and the investigation of related magnetic phenomena. Basically it consists of 6 multirange precision indicating instruments. Each is electrically isolated from the other and, therefore, can be used separately or in as many different combinations as may be necessary. They are mounted in the panel of a suitcase style portable case together with all necessary switching and binding posts for easy interconnection and operation. Such optional equipment as an Epstein Frame for core loss measurements, mutual inductors for permeability testing and a general purpose search coil to assist in measuring total flux, are offered as accessories. Excepting for power supplies, the Model MAT and its accessory items require no other equipment for the following specific tests:

1. Measurements of core loss in watts by using Epstein Frame specimens, EI cores or specimens of other configurations.

2. Measurements of AC permeability by using two mutual inductors, one for magnetizing currents up to approximately 1 amp and the other for currents above 1 amp.

3. The point by point determination of DC hysteresis loops (B-H curves).

4. Measurements of total flux of hard magnets.

5. Measurements of magnetic field strength.

6. General laboratory and production measurements of AC/DC voltage, current and power. The fluxmeter, in addition to its other functions, can be employed as a calibrated coulomb meter for the measurement of electrical discharges, and for determining the number of turns in an unknown coil (see pages 452-454).

In summation, the Model MAT is an extremely versatile magnetic testing set that can also be employed for a variety of other measurements. It is relatively low in price and easy to use for the capability which it provides. Measurements of cores loss are facilitated by including a tare compensation system so that readings in watts can be taken directly without the necessity of calculating and applying correction factors caused by the loading of other measuring instruments in the circuit and the potential circuit of the wattmeter itself. The user has only to divide through by the weight of his sample to obtain an answer in watts per pound.

Other economic and technical considerations are of importance. The test set is now the predominant standard employed in the magnetic materials industry, and where usage is common to quality control and incoming inspection departments, there is a provable, significantly better correlation of test results between the two. Since core loss testing is expensive as regards both the sample material that must be provided and the actual performance of measurements, any duplication of testing that can be avoided is an important saving.

SPECIFICATIONS

ELECTRICAL INDICATING INSTRUMENTS

General: All instruments unless otherwise noted, have the same specifications as the University Model of the same type described in detail in other sections of this catalog. (DC permanent magnet, moving coil types are listed in Section 3; AC/DC thermocouple types in Section 7; AC/DC dynamometer type wattmeters in Section 5.) The exceptions are the fluxmeter and the flux voltmeter which have no exact University Model counterparts. Excepting for scale length and case size the fluxmeter conforms to the specifications of the Model FM listed on pages 452-454, and the flux voltmeter to the specifications of the Model FLV listed on page 456.

All indicating instruments have 4" hand-drawn mirrored scales. They have diamond pivots and spring mounted jewels to provide virtually friction-free moving elements that can withstand abnormally severe operating conditions (excluding the fluxmeter whose design does not lend itself to their inclusion). All instruments are meticulously constructed in conformance with ASA specifications C-39 (where applicable). Accuracies listed are in terms of percent of full scale.

DC Ammeter: Accuracy .5%; 60/75 scale divisions printed 0-30/75/150. Range changing is by binding posts.

Range:	.03	.075	.15	.3	.75	1.5	3	7.5	15	30 amps
Approx. Resist.:	4	1.7	1	.5	.2	.1	.05	.02	.01	.005 Ω

AC/DC Ammeter: Accuracy .75%; thermocouple type, true rms response irrespective of waveform; frequency range DC and 7 cps to 5000 cps; 100 scale divisions printed 0-50/100/200; range changing is switch controlled. Automatic overload protection safeguards the thermocouple for overloads of 500% or 10 amps, whichever is the lesser figure.

Range:	.05	.1	.2	.5	1	2	5 amps
Approx. Resist.:	5	3.75	2.2	.95	.5	.25	.1 Ω

NOTE A: A Type 357 Thermocouple Replacement Feature is included for the user's convenience in the event the thermoelement is inadvertently overloaded beyond the rating of its protection system. Thermocouples can be replaced in the field without the necessity of returning the test set for recalibration. Replacements are supplied with correction curves. A complete description of the Type 357 Thermocouple Replacement Feature is given on page 153 of Section 2. If spare thermocouples are ordered at the same time as the test set they can be supplied in most cases within the accuracy of the thermocouple ammeter without the necessity of applying correction factors. When ordering, specify "Type 357 Replacement Thermocouple." If additional thermocouples are ordered at a later date than the test set specify the serial number of the indicating instrument in which a replacement is to be made. **Price:** $60.00 per thermocouple.

AC/DC Voltmeter. Accuracy .75%; thermocouple type, true rms response irrespective of waveform; frequency range DC and 7 cps to 4000 cps; 60/75 scale divisions printed 0-30/75/150. Range changing is switch controlled. *Automatic overload protection safeguards the thermocouple for overloads of 5000% or 600 v whichever is the lesser figure.

Range:	15	30	75	150	300 v
Sensitivity:	All ranges 500 Ω/v				

NOTE A: A Type 357 Thermocouple Replacement Feature is included as described in Note A of the specifications for the AC/DC thermal ammeter. **Price:** $60.00 per replacement thermocouple.

***NOTE B:** The automatic overload protection system starts to clip when peak to rms ratios greater than 4 to 1 are encountered. If the instrument is used with excitation in the saturation region of square loop type materials it tends to read lower than the actual applied voltage. *This does not occur in normal core loss or permeability testing.* However, provision is made for the simple disconnection of the overload protection system by the user in the event it is found desirable to do so in a particular measurement.

AC Flux Voltmeter: Accuracy .5%; full wave rectified, average reading instrument (average volts × 1.111); scale reads true rms only on a sinusoidal waveform; frequency range DC and 25 cps to 1000 cps; 60/75 scale divisions printed 0-15/30/75/150/300; range changing is switch controlled.

Range:	15	30	75	150	300 v
Sensitivity:	All ranges 3333 Ω/v				

AC/DC Single Phase Wattmeter: Accuracy .75% when used from 100% PF down to 50% PF, 1% when used below 50% PF down to 20% PF; frequency range DC & 25 cps to 500 cps, excepting the 12.5 v range DC & 50 cps to 70 cps and the 25 v range DC & 25 cps to 125 cps; approx. 60 cps burden 1.5 va; approximate sensitivity of potential circuit 80 Ω/v; 100/80 scale divisions printed 0-5/10/20/40; *selection of all watt ranges is switch controlled.*

RANGES

Volts	Normal Amps at 100% PF	Maximum Amps	Watts
12.5	.2	2	2.5
12.5	.4	4	5
25	.2	2	5
25	.4	4	10
50	.2	2	10
50	.4	4	20
100	.2	2	20
100	.4	4	40
200	.2	2	40
200	.4	4	80

NOTE A: Volt ranges may be used at 160% of nominal rating without loss of accuracy. Maximum current ratings enable the wattmeter to be employed at power factors down to 10% without overloading its current circuit. Accuracy in this area of PF varies to 3% depending on the range and frequency being measured, but results are reproducible within the normal precision of the instrument.

NOTE B: Current ranges can be increased by the use of the Model TR Type 2 Transformer. (See Section 10.)

DC Fluxmeter: Accuracy .5% on X1 and X3 ranges, all other ranges accuracy 1%; basic sensitivity 10,000 lines (maxwells) per division using a 15Ω, 1 turn search coil; 100 division scale printed 50-0-50; range changing is switch controlled.

Switch Position	Full Scale Range in Lines	Sensitivity in Lines/Div.
X1	500,000	10,000
X3	1,500,000	30,000
X10	5,000,000	100,000
X30	15,000,000	300,000
X100	50,000,000	1,000,000

NOTE A: Sensitivity of the fluxmeter is stated in terms of its being used with a 15Ω 1 turn search coil. Sensitivity increases on a pro rata basis when a greater number of turns are wound on the search coil (provided the 15Ω limitation is observed). A general purpose 10 turn search coil is offered as an "Optional Accessory." When it is used with the fluxmeter, sensitivity is increased by a factor of 10 to become 1000 lines per division.

OPTIONAL ACCESSORIES

1. Model EPS: An **Epstein Frame** having replaceable tube liners and constructed in accordance with ASTM specifications as listed in A343-54.

The Epstein Frame is essentially a transformer whose core is the specimen to be tested. It consists of four solenoids, each having a primary and secondary winding surrounding 4 sides of a square magnetic circuit and a mutual inductor to compensate for air flux within the solenoids. A total of 700 turns, equally divided over the 4 solenoids, is wound on non-magnetic, non-conducting forms and mounted on a 14½" x 14½" x ¾" bakelite base. The center line of the solenoids on opposite sides of the square are 25 cm apart. The frame is for use with a test specimen made of strips of sheet material 28 cm long x 3 cm wide. The air flux compensating inductor is mounted in the center of the frame and internally connected to it. The compensator eliminates the effects of air flux so that only the intrinsic flux of the specimen itself is measured.

It is recommended that spare replaceable liners be obtained at the time of purchasing the frame.

2. Model GPS: A 10 turn, 15Ω general purpose *Search Coil* for use with the fluxmeter for the measurement of flux density. Special search coils are not available from Sensitive Research but information can be supplied as to their construction. A more complete description of the Model GPS standard search coil and its application is given on page 452.

MODEL MU

3. Model MU: Two *Mutual Inductors* are available to be employed with the Model MAT to make permeability measurements. The inductors are a direct ASTM design. The Code MULO, for low current use up to approximately 1 amp, has a greater number of turns for a high value of mutual inductance. The Code MUHI for use at currents higher than 1 amp to approximately 5 amps has a fewer number of turns and therefore is smaller in size and less sensitive.

In operation the primary winding of the mutual inductor is inserted in series with the exciting winding on the test sample, and a flux voltmeter reading is taken across the secondary. The secondary reading multiplied by the calibration factor supplied with each unit is the crest ampere value of the exciting current. This current value is used in the formula $H = \frac{.4\pi NI \text{ crest}}{l}$ and the value of H can be computed. β is determined from the flux voltmeter reading across the secondary by formula $\beta \max = \frac{E}{4.44 \text{ fN \& A} \times 10^{-8}}$. Permeability is then $\frac{\beta \max}{H \max}$

The Model MAT is supplied in a sturdy 26" x 19" x 18" deep oak case with removable hinged cover and carrying handle. There is a compartment for test leads, clips and other accessories. Approximate weight is 75 lbs. net; 170 lbs. shipping. Operating instructions as well as ASTM booklets A343, A341, A340 and A34 are furnished.

Model	Description	Code	Price
MAT	Universal Magnetic Testing Set	MATSET	$2975.00
EPS	Epstein Frame (Replaceable Liners for Epstein Frame $15.00/set of 4)	EPSMAT	450.00
MU	Mutual Inductor (up to 1 amp)	MULO	225.00
	Mutual Inductor (over 1 amp to 5 amps)	MUHI	175.00
GPS	General Purpose 10 Turn Search Coil for Fluxmeter		40.00

MODEL COL
AC CORE LOSS TEST SET

GENERAL DESCRIPTION

The Model COL is a production type test set designed specifically for measuring AC core loss and excitation currents as described in the American Society for Testing Materials, publication A 343-54, sections 5 to 7, pages 385 to 391. It differs from the Model MAT, a multipurpose magnetic testing set previously described on pages 459 to 461 in that it provides faster, easier operation at higher accuracy in a limited area of measurement. Whereas each indicating instrument in the Model MAT can be used separately if desired, thereby preserving the utmost in versatility, the instruments in the Model COL are completely connected internally and can only be employed as a fixed combination for measurements as specified in certain ASTM procedures.

The Model COL can be used either with an Epstein Frame or with suitable test coils wound on stacks of EI laminations. It is intended for measurements of power transformer materials at relatively high densities, such as the measurement of va and core loss at 10 kilogausses and/or 15 kilogausses, and at 60 cps and/or 400 cps. An internal tare compensation system enables direct reading of both watts and current, without correction, and results in a significant saving of time during production testing.

The flux voltmeter in the test set has excellent resolution as provided by a 6.3" scale length. This is an important advantage because any errors in setting the test voltage are magnified in the watt readings at high densities. The error in the exciting current at 15 kilogausses caused by the voltage error may be 10 to 20 times as large as the voltage error.

SPECIFICATIONS

General: All instruments in the Model COL have hand-drawn mirrored scales, diamond pivots and spring mounted sapphire jewels, and automatic temperature compensation. They are constructed to conform to ASA specifications C-39 (where applicable). *Range changing is completely switch controlled.* The individual instruments comprising the test set are listed below. For a more complete description of each type, the reader is referred to the listings for portables in other parts of this catalog section and Sections 7 (thermocouple instruments) and 5 (wattmeters). Accuracies listed are in terms of percent of full scale.

AC/DC Ammeter: Accuracy .5%; thermocouple type, true rms response regardless of wave form; frequency range DC and 7 cps to 2000 cps; 100 division 4" scale printed 0-1/2/5; automatic overload protection safeguards the thermocouple for overloads of 500% or 10 amps, whichever is the lesser figure.

Range: .05/.1/.2/.5/1/2/5 amps

NOTE A: A Type 357 Thermocouple Replacement Feature is included as described on page 460 in Note A of the specifications for the AC/DC thermal ammeter in the Model MAT. **Price** $60.00 per thermocouple.

The AC voltmeter with true rms response and the AC flux voltmeter that reads average volts x 1.111 are combined in a single dual purpose instrument numbered 1 and 2 below. Readout is on separate scales drawn on a single scale plate. In operation, when a wave form check is required the readings of the rms instrument can be quickly compared to that of the average reading instrument by merely flicking a switch.

1. AC/DC Voltmeter: Accuracy .5%; thermocouple type, true rms response regardless of wave form; frequency response DC and 7 cps to 2000 cps; 150 division 6.3" scale printed 0-30/75/150; automatic overload protection safeguards the thermocouple for overloads of 5000% or 600 v, whichever is the lesser figure.

Range: 15/30/75/150/300 v

NOTE A: A Type 357 Thermocouple Replacement Feature is included as described on page 460 in Note A of the specifications for the AC/DC thermal ammeter in the Model MAT. **Price** $60.00 per thermocouple.

NOTE B: The automatic overload protection system starts to clip when peak to rms ratios greater than 4 to 1 are encountered. *This is not a factor in normal core loss or permeability testing.* However, provision is made for the simple disconnection of the overload protection system by the user if desirable.

2. AC Flux Voltmeter: Accuracy .5%; full wave rectified average reading instrument (average volts x 1.111); scale reads true rms only on a sinusoidal wave form; frequency range 25 to 1000 cps; 150 scale divisions printed 0-15/30/75/150/300.

Range: 15/30/75/150/300 v

AC/DC Single Phase Wattmeter: Accuracy .75% when used from 100% PF down to 50% PF, 1% when used below 50% PF down to 20% PF; frequency range DC & 25 cps to 500 cps, excepting the 12.5 v range DC & 50 cps to 70 cps and the 25 v range DC & 25 cps to 125 cps; 100/80 scale divisions printed 0-5/10/2/40. Ranges as follows:

Volts	Normal Amps at 100% PF	Maximum Amps at Minimum PF	Watts
12.5	.2	2	2.5
12.5	.4	4	5
25	.2	2	5
25	.4	4	10
50	.2	2	10
50	.4	4	20
100	.2	2	20
100	.4	4	40
200	.2	2	40
200	.4	4	80

Note A: Additional specifications as per notes "A" and "B" on page 461 in the description of the wattmeter in the Model MAT.

OPTIONAL ACCESSORIES

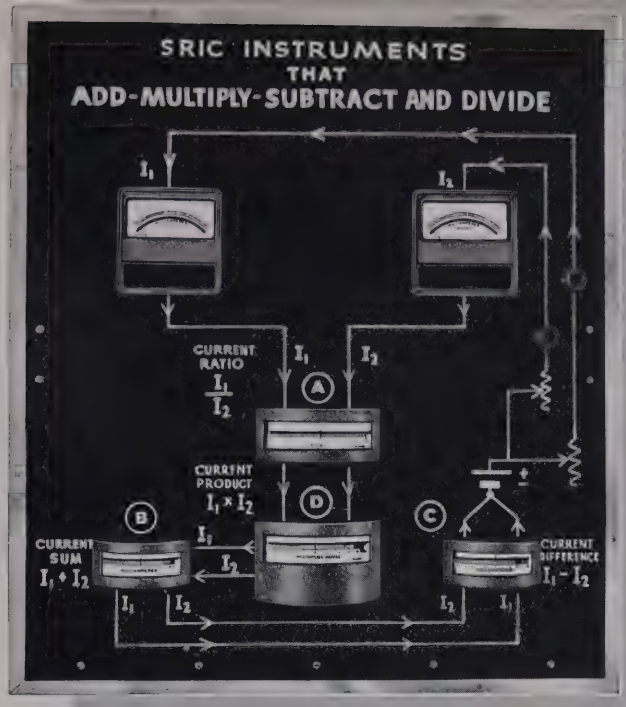
Model EPS is an *Epstein frame* having replaceable tube liners and constructed in accordance with ASTM specifications as listed in A343-54. See description on page 461.

The Model COL is supplied in a 22" x 13½" x 9" formica case, with removable hinged cover and carrying handle. Approximate weight is 35 lbs. net, 150 lbs. shipping. Operating instructions as well as ASTM publication A343 are supplied.

Model	Description	Code	Price
COL	Core Loss Test Set	CORLOS	$1810.00
EPS	Epstein Frame	EPSMAT	450.00
	(Replaceable Liners for Epstein Frame $15.00/set of 4)		

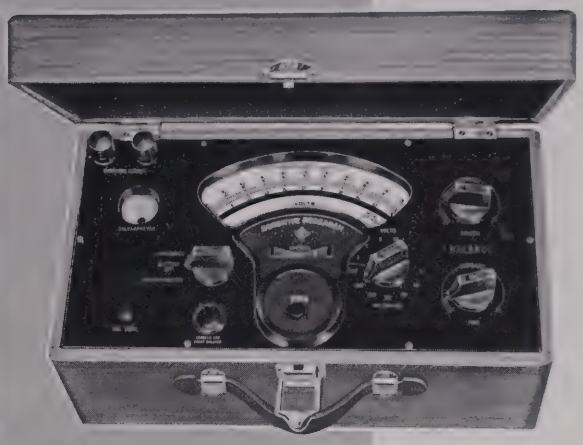
Prices and Specifications Subject to Change Without Notice.

Printed in U.S.A. 75-1



INSTRUMENTS ILLUSTRATED IN PANEL

MODELS
Ⓐ RAEW-7A
ⒷⒸ JDJW-4A
Ⓓ DYSPEW-5A



MODEL PV

STERLING CO.
Manufacturers' Representatives
[illegible] SOUTH DIXIE [illegible]
[illegible] OHIO
[illegible]

Portable and Panel
AC and DC and AC/DC
SPECIAL PURPOSE
ELECTRICAL INDICATING INSTRUMENTS

SCALE DRAWING MACHINE FOR ELECTRICAL INDICATING INSTRUMENTS

Model	Description	Page
SD	.5% DC Differential Instruments. 5.2" scale length	502-503
JD	.5% DC Differential Instruments. 3.25" scale length	503
JDJW-4A	.5% DC Differential Edgewise Panel Instruments. 4" scale length	504
RA	.25% DC Ratiometers. 5.2" scale length	505
DYSP	.25% AC/DC Current Product Instruments. 5.2" scale length	506
PV	.35% DC Potentiometer Voltmeters. 5.2" scale length	507
ZR	.5% DC Zero Resistance Microammeters and Milliammeters. 5.2" scale length	508
FRE	.25% Frequency Meters. 6.3" scale length	509
E	.2% AC Form Factor Instruments. 6.3" scale length	510
SCAMA	Scale Drawing Machine	511
	Edgewise Panel Case Dimensions	512

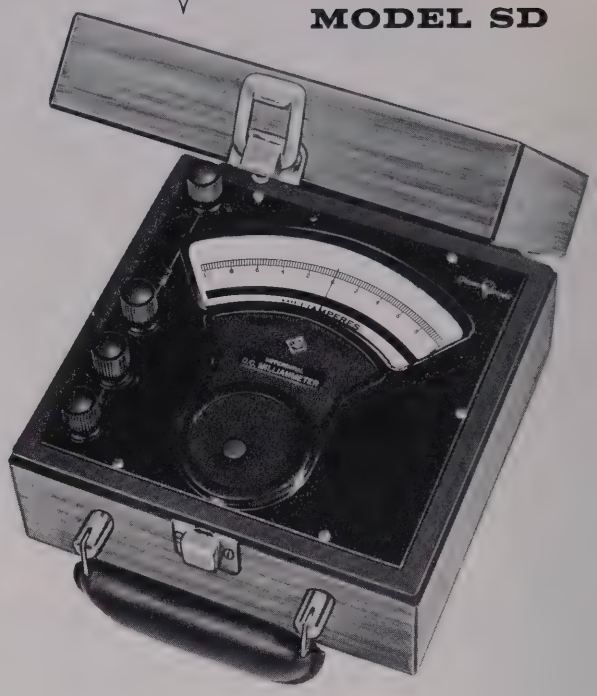
Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N. Y.

Refer to model descriptions for availability of portable instruments in Types EW-5A and EW-7A cases for panel mounting.

Symbol of Quality

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

MODEL SD



SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic; magnetic
RANGE CHANGING	Binding posts; for switch control see "Optional Specifications" below
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7½" x 7¾" x 4¼" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	7 lbs. net; 24 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. Normally supplied "zero center." Special "zero left" instruments available at additional cost of $25.00. See "General Notes" page 504.

2. Multirange instruments are available switch controlled at an additional cost of $25.00 (Case size 7½" x 7¾" x 6 1/16").

3. Three range instruments and non-catalog ranges (including differential millivoltmeters and voltmeters) are available on special order. Correspondence required.

PANEL INSTRUMENTS

The Model SD is also available for vertical panel mounting in the shallow (deep case if supplied switch controlled) EW-5A (5" scale length) edgewise panel case. For dimensions see page 512.

Performance characteristics are the same as listed for the portable type. See "Optional Specifications" above.

Specify: Model SDEW-5A and code word of portable instrument having ranges desired.

Price: Add $25.00 to price of code word selected. ($30.00 if switch controlled.)

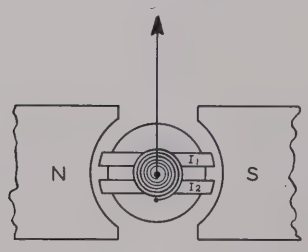


Figure 1.

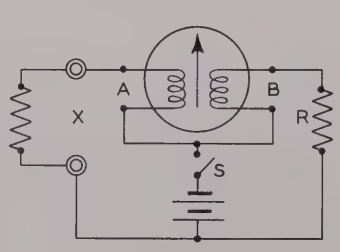


Figure 2.

GENERAL DESCRIPTION

The Model SD compares or measures the difference between two DC currents or voltages. Its moving element consists of two coils wound together on a single form. (See Figure 1.) Each coil has the same deflectional linearity and full scale sensitivity, and is insulated from the other to withstand a potential difference of 100 volts continuous or 250 volts momentary (1 minute max.). Separate binding posts are provided for each moving coil element.

In operation, if the current to each coil is identical in magnitude but opposite in polarity the net result is zero and the pointer does not deflect ($I_1 - I_2 = 0$). (When the inputs have the same polarity, the pointer deflection is proportional to the sum of the currents.) If there is only a very small difference between inputs, it is indicated by a pointer deflection either to the right or left of the zero scale line.

The uniqueness of the differential instrument is its ability to withstand maximum sustained current overloads of as much as 1000% (ranges of 50 ma and less), which results in a tenfold increase in absolute accuracy and scale resolution. As an example of an actual application of the differential instrument, consider the circuit shown in Figure 2. If the instrument, diagramed as Coils A and B, has a range of 100-0-100 microamperes, comparison of an unknown resistance (X) to a standard resistance (R) can be made to an accuracy of .05%, even though the absolute accuracy of the instrument is only ±.5% of full scale. This is accomplished by simply testing at 10 × normal rated current or, in this case 1 milliampere. The instrument still deflects for differences between the two inputs to coils A and B based on the fundamental sensitivity of 100 microamperes. Therefore, if each ½ scale division represents ±.5% of full scale at normal rated current, it represents ±.05% of full scale at 10 × that current.

Model SD Differential Microammeters

SINGLE RANGE

Full Scale Microamperes	Approx. Resist. Each Winding Ω	Max. Current Micro-amperes	Scale Divisions	Code	Price
*2/0/2	3900	20	40-0-40	SDIFFA	$266.00
5/0/5	2600	50	50-0-50	SDIFER	255.00
10/0/10	1220	100	50-0-50	SDIFIK	245.00
30/0/30	100	300	30-0-30	SDIFOS	243.00
50/0/50	26	500	50-0-50	SDIFUT	238.00
100/0/100	5	1000	50-0-50	SDIFYE	238.00
500/0/500	2	5000	50-0-50	SDIFAL	238.00

DOUBLE RANGE

5/0/5 }	2900	50	50-0-50 }	SDDIUX	305.00
50/0/50 }	15000	500	}		
10/0/10 }	1220	100	50-0-50 }	SDDIOO	295.00
100/0/100 }	5000	1000	}		
50/0/50 }	26	500	50-0-50 }	SDDIAX	288.00
500/0/500 }	200	5000	}		

* *Not available with "zero left". Accuracy 1%.*

Model SD Differential Milliammeters

SINGLE RANGE

Full Scale Milliamperes	Approx. Resist. Each Winding Ω	Max. Current Milli-amperes	Scale Divisions	Code	Price
1/0/1	10	10	50-0-50	SDIFBO	$238.00
2/0/2	7	20	40-0-40	SDIFCA	238.00
5/0/5	5	50	50-0-50	SDIFDY	238.00
10/0/10	4	100	50-0-50	SDIFEE	238.00
25/0/25	2	250	50-0-50	SDIFFI	248.00
50/0/50	1.0	500	50-0-50	SDIFGY	248.00
100/0/100	.7	750	50-0-50	SDIFHA	253.00
200/0/200	.5	1500	40-0-40	SDIFIP	253.00
500/0/500	.1	3000	50-0-50	SDIFJO	258.00

DOUBLE RANGE

1/0/1 }	10	10	50-0-50 }	SDDIFO	288.00
10/0/10 }	6	100	}		
2/0/2 }	7	20	40-0-40 }	SDDIFI	298.00
20/0/20 }	2.5	200	}		
10/0/10 }	4	100	50-0-50 }	SDDIFE	303.00
100/0/100 }	.5	750	}		
20/0/20 }	2.5	200	40-0-40 }	SDDIFU	303.00
200/0/200 }	.25	1500	}		
50/0/50 }	1.0	500	50-0-50 }	SDDIFY	308.00
500/0/500 }	.1	3000	}		

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

(Available for mounting in a horizontal panel. See below.)

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 3.25"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
RANGE CHANGING	Binding posts only
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Moulded black bakelite; 6 1/16" x 4 5/8" x 2 7/16" h.
APPROX. WEIGHT	3 1/2 lbs. net; 15 lbs. shipping

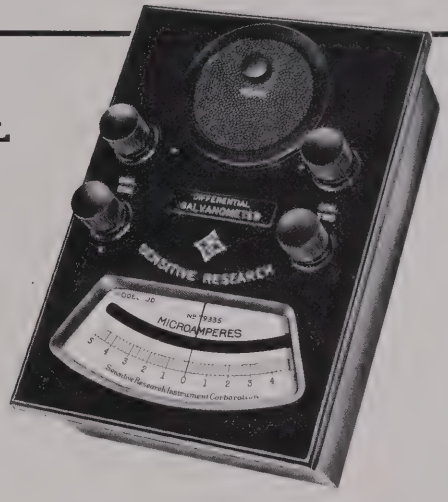
All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

Normally supplied "zero center." "Zero left" is available at additional cost of $25.00. (See "General Notes", page 504.)

The Model JD is a small portable differential instrument similar in design to the Model SD (see pages 502-503) but with a shorter scale length that permits a somewhat higher sensitivity. Two pairs of input binding posts are normally mounted on the rear of the case, and are so furnished unless otherwise specified. However, they are available on the bottom of the case for flush horizontal panel mounting, or on the top as shown above. (See diagrams on page 213 of catalog Section 3 if further clarification of binding post locations is desired.)

MODEL JD



Model JD Differential Microammeters

Range	Approx. Resist. Each Winding Ω	Max. Current	Scale Divisions	Code	Price
*2/0/2	3000	20 μa	20-0-20	JIFFA	$216.00
5/0/5	2600	50 μa	25-0-25	JIFER	205.00
10/0/10	220	100 μa	20-0-20	JIFIK	195.00
30/0/30	15	300 μa	30-0-30	JIFOS	193.00
50/0/50	4.8	500 μa	25-0-25	JIFUT	188.00
100/0/100	3.7	1000 μa	20-0-20	JIFYE	188.00
500/0/500	2.7	5000 μa	25-0-25	JIFKO	188.00

* *Not available with "zero left". Accuracy 1%.*

Model JD Differential Milliammeters

1/0/1	10	10 ma	20-0-20	JIFBO	188.00
2/0/2	7	20 ma	20-0-20	JIFCA	188.00
5/0/5	5	50 ma	25-0-25	JIFDY	188.00
10/0/10	4	100 ma	20-0-20	JIFFEE	188.00
25/0/25	2	250 ma	25-0-25	JIFFI	198.00
50/0/50	1.0	500 ma	25-0-25	JIFGY	198.00
100/0/100	.7	750 ma	20-0-20	JIFHA	203.00
200/0/200	.5	1500 ma	20-0-20	JIFIP	203.00
500/0/500	.1	3000 ma	25-0-25	JIFJO	208.00

COMPACT EDGEWISE PANEL DIFFERENTIAL INSTRUMENTS

MODEL JDJW-4A

SPECIFICATIONS

DC EDGEWISE PANEL INSTRUMENT

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 4"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2-3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic; magnetic
RANGE CHANGING	Binding posts
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Aluminum; black wrinkle finish; see page 512 for dimensions
APPROX. WEIGHT	5 lbs. net; 16 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

MODEL JDJW-4A
DIFFERENTIAL MICROAMMETERS

Range	Approx. Resist. Each Winding Ω	Max. Current	Scale Divisions	Code	Price
*2/0/2	3900	20 μa	20-0-20	JDIFFA	$226.00
5/0/5	2600	50 μa	25-0-25	JDIFER	215.00
10/0/10	1220	100 μa	20-0-20	JDIFIK	205.00
30/0/30	100	300 μa	30-0-30	JDIFOS	203.00
50/0/50	26	500 μa	25-0-25	JDIFUT	198.00
100/0/100	5	1000 μa	20-0-20	JDIFYE	198.00
500/0/500	2	5000 μa	25-0-25	JDIFAL	198.00

* *Not available with "zero left". Accuracy 1%.*

MODEL JDJW-4A
DIFFERENTIAL MILLIAMMETERS

1/0/1	10	10 ma	20-0-20	JDIFBO	198.00
2/0/2	7	20 ma	20-0-20	JDIFCA	198.00
5/0/5	5	50 ma	25-0-25	JDIFDY	198.00
10/0/10	4	100 ma	20-0-20	JDIFEE	198.00
25/0/25	2	250 ma	25-0-25	JDIFFI	208.00
50/0/50	1.0	500 ma	25-0-25	JDIFGY	208.00
100/0/100	.7	750 ma	20-0-20	JDIFHA	213.00
200/0/200	.5	1500 ma	20-0-20	JDIFIP	213.00
500/0/500	.1	3000 ma	25-0-25	JDIFJO	218.00

OPTIONAL SPECIFICATIONS

1. Normally supplied "zero center". "Zero left" is available at additional cost of $25.00. (See "General Notes" below.)

2. Non-catalog ranges are available. Differential instruments for the measurement of volts or millivolts can also be supplied. Correspondence is required for all special instruments.

The Model JDJW-4A is a differential edgewise panel instrument for flush vertical panel mounting. Its design and sensitivity are the same as listed for the Model SDEW-5A (see pages 502-503), excepting it has a shorter scale length and is available as a single range instrument only.

GENERAL NOTES ON DIFFERENTIAL INSTRUMENTS

1. Accuracy of "zero center" instruments is expressed in terms of percentage of full scale, where full scale is defined as the sum of the left and right of zero full scale values. (Example: Instrument with a range of 5-0-5 milliamperes has an accuracy of ±.5% of 10 milliamperes.)

2. "Zero left" and "zero center" instruments have similar specifications for an equivalent total scale deflection. (Example: A 0-10 ma "zero left" instrument has the same performance characteristics, resistance and maximum current rating as a 5-0-5 ma instrument.)

3. All instruments are normally furnished with knife edge pointers and standard scale markings. Lance type pointers can be supplied if specified. Special scales can be drawn but correspondence required.

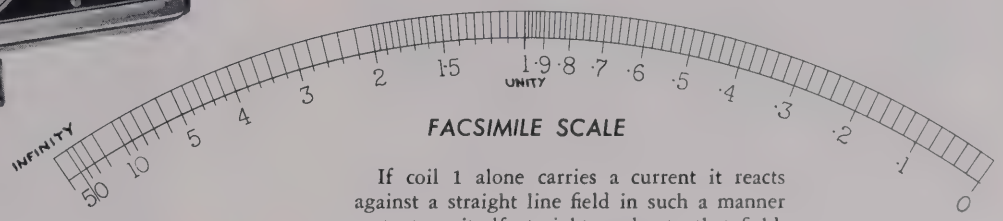
4. Differential instruments are constructed to take momentary overloads of as much as 10 × rated maximum current values for periods not exceeding 5 seconds. However, in usage, it is necessary to apply simultaneous inputs to the coils to preclude possible mechanical damage to the pointer. This applies for ranges up to and including 50 ma. Individual data cards must be consulted for overload data of instruments having ranges above this value.

RATIOMETER

MODEL RA

GENERAL DESCRIPTION

The Model RA divides or measures the ratio of two currents or voltages. Figure 1 shows the basic construction of the instrument. The moving element consists of two electrically isolated coils permanently fixed in relation to each other and to the pointer in the positions shown in the diagram. The pointer and coil assembly is free to move as a unit and there are no restoring springs to restrict or control its movement. Current is introduced into coils 1 and 2 by means of fine gold ligaments which give a negligible mechanical restraining force.



FACSIMILE SCALE

If coil 1 alone carries a current it reacts against a straight line field in such a manner as to turn itself at right angles to that field. This positions the entire moving coil and pointer assembly so that the pointer indicates at "Infinity" on the scale. If current is applied to coil 2 only, that coil turns at right angles to the field and carries the entire moving assembly to the "zero" position. If both coils are energized simultaneously, each attempts to accomplish the above movement, and the moving coil and pointer assembly assumes an intermediate position so that the forces of coil 1 and coil 2 are balanced. When the currents to both coils are equal, deflection is halfway between the extremes and the ratio of coil 1 current to coil 2 current is unity. (This is the position shown in the diagram.) For all other values of current ratio the moving assembly takes up intermediate positions. As soon as sufficient current is applied to either coil to overcome the small resistance of pivot friction and ligament forces present, position is determined solely by the ratio of currents in both coils, and not by the magnitude of each current.

The RATIO METER has almost all the abilities of the differential instrument except that its range of comparison goes from zero to infinity. The fact that the comparison is on the basis of a quotient instead of a difference makes it ideally suited for uses such as measuring the resistance of heating elements and other components while the current is flowing. (EXAMPLE: Connect one coil in series with the current supplied and the other coil with suitable resistances across the load. A continuous measurement of resistances may be made regardless of current or voltage variations since the instrument indicates only changes in RATIO, not in individual values.)

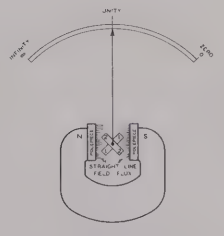


Figure 1.

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of ratio when operated at maximum range current. Prorated to 1% of ratio when operated down to minimum range current.
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	3-4 seconds
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
RANGE CHANGING	Switch controlled
CASE	Formica; 7½" x 7¾" x 6$\frac{1}{16}$" h.; black bakelite panel; hinged cover; carrying strap.
APPROX. WEIGHT	9 lbs. net; 15 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

OPTIONAL SPECIFICATIONS

1. The Model RA can be furnished to indicate voltage ratios. Correspondence required.

2. Either the standard Model RA or any single range instrument can be furnished with an expanded scale. Maximum expansion is from ratios of 3 to .3. Add $25.00 to price of instrument.

PANEL INSTRUMENTS

The Model RA is also available for vertical panel mounting in the deep EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. Single range instruments are supplied in the shallow case. For dimensions, see page 512. Performance characteristics are the same as listed for the portable type.

Specify: Model RAEW-5A or RAEW-7A and code word "RATIO". If single range only desired, specify range and do not list the standard code word.

Price: Add $30.00 to price of Code RATIO. ($25.00 if single range.)

MULTIRANGE RATIOMETER

RANGES (each coil) Minimum Current	Maximum Current	Res. Ohms	Code	Price
50 Microamps	1 Milliamp	1500	RATIO	$335.00
.5 Milliamp	10 Milliamps	150		
5 Milliamps	100 Milliamps	15		
50 Milliamps	1000 Milliamps	1.5		

SINGLE RANGE RATIOMETERS

If an instrument with a single minimum to maximum current range is desired, any of the above ranges is available. Price $315.00.

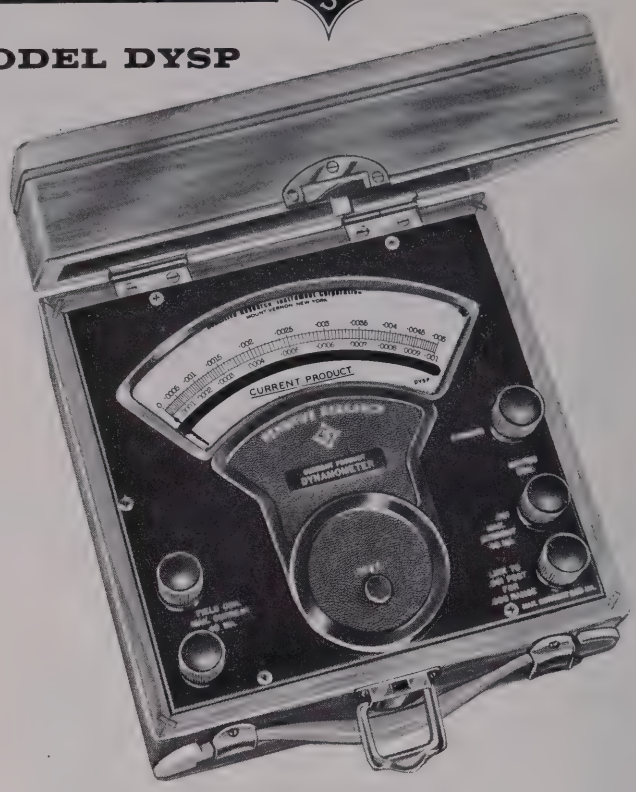
SPECIFICATIONS

AC/DC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of full scale
FREQUENCY	DC and 25-500 cps; or any single frequency between 25-2000 cps.* (See "Optional Specifications" below.)
TYPE	Electrodynamometer
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	3 seconds
DAMPING	Air vane
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic; magnetic
RANGE CHANGING	Binding posts
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7½" x 7¾" x 6$\frac{1}{16}$" h.; black bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	9 lbs. net; 12 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

MODEL DYSP



OPTIONAL SPECIFICATIONS

Special single or multirange instruments are available from .000025 amperes² full scale.

* Instruments with special ranges can sometimes be furnished only at reduced accuracy if for use over a frequency span of DC and 25-500 cps. Most instruments can be calibrated at a particular frequency from 25-2000 cps without affecting accuracy. Correspondence is required.

PANEL INSTRUMENTS

The Model DYSP is also available for vertical panel mounting in the deep EW-5A (5″ scale length) edgewise panel case. For dimensions see page 512.

Performance characteristics are the same as listed for the portable type.

Specify: Model DYSPEW-5A and code word of portable instrument having ranges desired.

Price: Add $30.00 to price of code word selected.

GENERAL DESCRIPTION

The Current Product Instrument has separate stationary field and moving coil circuits for independent current inputs. The torque of the movement is proportional to $I_a\ I_b\ \text{Cos}\theta$ when I_a is the current in the field circuit, I_b is the current in the moving coil circuit and θ is the phase angle between the two currents. For DC this simplifies to $I_a\ I_b$ and the meter indicates the product of the input currents directly.

The division of current between the stationary field coils and the moving coil is sometimes of importance. When either input is extremely low or high, correspondence giving all application data is advisable before placing an order.

In the ranges listed below the term "amperes²" is the unit of current product. As an example, if the two inputs are .01 amperes each, the scale is drawn 0-.0001 amperes².

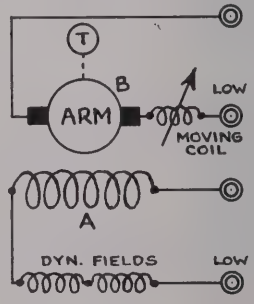


Figure 1.

Circuit of Model DYSP measuring efficiency of a motor. A single reading combines the product of A and B (and Cos θ if operation is on AC).

CURRENT PRODUCT MILLIAMMETERS

Ranges in Current Product	COIL SPECIFICATIONS — Moving Coil	Stationary Field Coils — Series	Stationary Field Coils — Parallel	Scale Div.	Code	Price
.001/.002 Amp²	Res. 7 ohms Induct. .6 mh Max. cur. 40 ma	Res. 338 ohms Induct. 520 mh Max. cur. 40 ma	Res. 84 ohms Induct. 130 mh Max. Cur. 80 ma	100	DYPOB	$355.00
.02/.04 Amp²	Res. 6 ohms Induct. .6 mh Max. cur. 160 ma	Res. 9.2 ohms Induct. 18 mh Max. cur. 400 ma	Res. 2.3 ohms Induct. 4.5 mh Max. cur. 800 ma	100/80	DYPOK	$325.00
.25/.5 Amp²	Res. 40 ohms Induct. 1.55 mh Max. cur. 750 ma	Res. 1.5 ohms Induct. 18 mh Max. cur. 1 Amp.	Res. .4 ohms Induct. 4.5 mh Max. cur. 2 Amp.	125/100	DYPOX	$325.00

MODEL PV

SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.35% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying strap
APPROX. WEIGHT	14½ lbs. net; 18 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

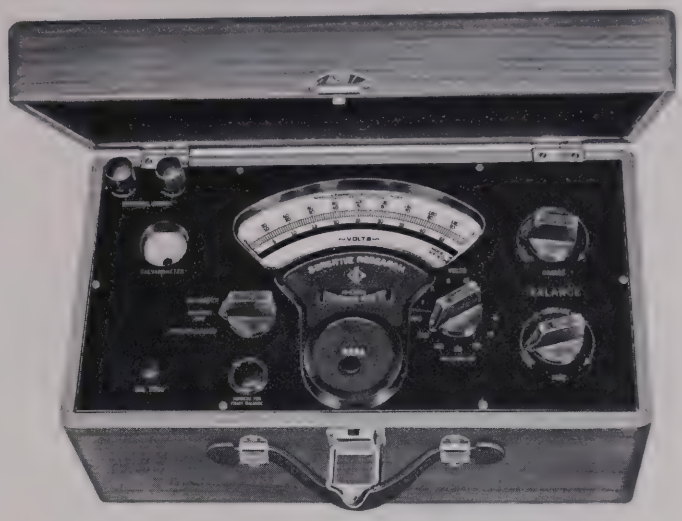
OPTIONAL SPECIFICATIONS

1. A polarity reversing switch is available. Price $30.00.

GENERAL DESCRIPTION

The Model PV is a 5000 Ω/v or 1000 Ω/v DC voltmeter as well as a potentiometer voltmeter with infinite resistance at null. While it was originally developed for use in making corrosion and electrolysis measurements, it also has great value in any application where an excessive current drain cannot be tolerated.

An internal battery capable of providing a maximum emf that is at least equivalent to the highest voltage measuring range of the instrument, supplies a rugged indicating voltmeter connected to a sensitive galvanometer. (See Figure 1.) In operation, as a potentiometer voltmeter, coarse and fine rheostat controls mounted on the instrument panel adjust the IR drop across the voltmeter until there is no deflection of the galvanometer. When the galvanometer is balanced, the drop across the voltmeter equals the unknown emf applied from the external circuit under test, and the voltmeter is effectively an infinite resistance measuring instrument that is not drawing current. In those instances where circuit loading is unimportant, the instrument can be used as a direct reading conventional voltmeter. The galvanometer sensitivity is such that 1 volt can be detected through a resistance of 10 megohms. A push button on the panel can be depressed to increase the galvanometer sensitivity by a factor of 10. Standard batteries are used for easy field replacement.



In electrolysis work, the use of the Model PV eliminates the possibility of errors occurring due to high resistance electrodes and/or their polarization.

The Model PV is particularly effective when a number of thermocouples stationed at varying distances must be measured, and it is desirable to do so at a central location. Its use safeguards against errors that would normally arise because of the differences in resistance that would be in series with the instrument when switching from station to station.

The Model HS with a sensitivity of up to 1,000,000 Ω/v is a high resistance direct reading portable voltmeter that also has wide application in corrosion applications. It is described in Section 3 on Page 206.

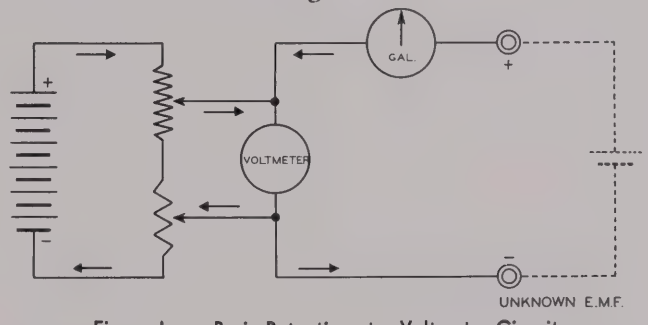


Figure 1. Basic Potentiometer Voltmeter Circuit

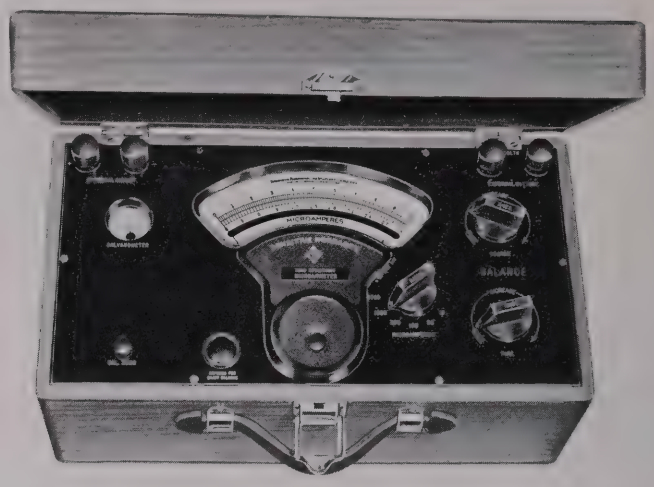
The design of the Rhodes Potentiometer Voltmeter was first suggested by George I. Rhodes, Vice President and Chief Engineer of Ford, Bacon & Davis, Inc., who used the instrument successfully in cathodic protection work and electrolysis measurements.

POTENTIOMETER MILLIVOLTMETERS AND VOLTMETERS

Range	SENSITIVITY as a potentiometer voltmeter	SENSITIVITY as a direct reading voltmeter	Scale Div.	Code	Price
2/20/200 Millivolts	infinite at null	(5000 Ω/v)	100	ZERLOM	$380.00
20/200/2000 Millivolts		(5000 Ω/v)	100	ZERMIL	380.00
2/10/20/100/200/1000/2000 Millivolts		(5000 Ω/v)	100	ZERRIT	385.00
2/5/10/20/50/100/200/500/1000mv/2/5/10/20 volts		(5000 Ω/v)	100	ZERUNI	410.00
20/50/100/200/500/1000mv/2/5/10/20 volts		(5000 Ω/v)	100	ZERAMP	405.00
5/10/20/50/100/200/500/1000mv/2/5/10 volts		(1000 Ω/v)	100	FORDBA	400.00

ZERO RESISTANCE MICROAMMETERS AND MILLIAMMETERS

MODEL ZR



SPECIFICATIONS

DC PORTABLE—HORIZONTAL USE

ACCURACY	.5% of full scale
TYPE	Permanent magnet, double pivoted moving coil
SCALE	Hand-drawn; 5.2"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2—3 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 13¾" x 7½" x 6⅜" h.; black bakelite panel; hinged cover; carrying handle.
APPROX. WEIGHT	10 lbs. net; 15 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

GENERAL DESCRIPTION

The Model ZR is a self contained direct reading electrical indicating instrument that measures DC microamperes and milliamperes while effectively introducing zero resistance into a circuit. It is particularly valuable for use in those applications where even a small amount of circuit loading causes appreciable errors, such as in corrosion and electrolysis work, and in particular, in the measurement of the output of photocells. It is also effective when used to indicate the internal resistance of electrolytic cells and high or medium resistance sources.

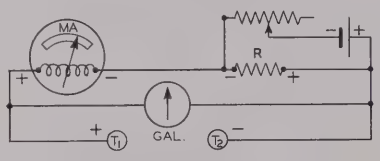


Figure 1
Basic Zero Resistance Circuit

The fundamental circuit is shown in Figure 1. An external battery supplies a voltage across a resistor in series with an indicating instrument, which in turn is in parallel with a sensitive galvanometer and the circuit to be measured. When the galvanometer is nulled by means of a coarse and fine control mounted on the instrument panel, the potential drop across the resistor is equal and opposite to that across the indicator and the net voltage at the measuring terminals is zero. The instrument deflection then is a true indication of the current flowing because the introduction of the Model ZR does not add to the circuit loading.

A push button on the panel can be depressed to increase the galvanometer sensitivity by a factor of 10. External batteries are required but not furnished.

In using a barrier layer photocell for measurement of light intensities over a wide range, the linearity of response is one of the limiting factors when used with conventional indicating instruments. The curves in Figure 2 show that this response varies with different values of instrument resistance. As the instrument resistance is made lower, the curves become more nearly a straight line. The conventional instrument becomes increasingly delicate and unsatisfactory when its resistance is reduced while its sensitivity is maintained—and this occurs before a flat photocell output is possible. The result, when using such a high sensitivity multirange current meter, is that the scale does not check from range to range and is not linear within a range.

The zero resistance instrument imposes no such difficulties. The range over any scale shows a straight line calibration; in fact, with only one standard intensity source to give a single point the complete calibration curve can be drawn with a straight edge. Under these conditions the readings are linear and accurate throughout the useful range of the cell. The only limitation is that point at which the self generated current of the cell begins to heat cell surfaces. The point at which it loses linearity is also the point at which the cell is damaged by over exposure.

The zero resistance instrument has been used very successfully in a photoelectric photometer for colorimetric chemical analysis for the accurate measurement of dilute solutions which absorb but a fraction of the incident light.

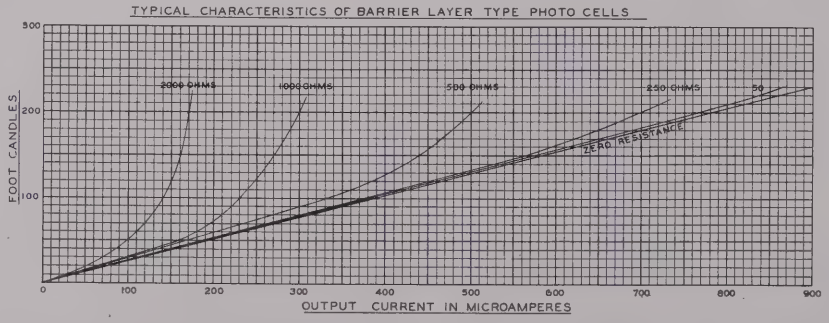


Figure 2.
Typical Characteristics of Barrier Layer Type Photo Cells

ZERO RESISTANCE MICROAMMETERS AND MILLIAMMETERS

Ranges in Microamps	Scale Div.	Code	Price
10/30/100/300/1000/3000	100/60	ZERMUL	$415.00

Ranges in Milliamps	Scale Div.	Code	Price
.1/.3/1/3/10/30	100/60	ZERMET	$396.00
1/3/10/30/100/300	100/60	ZERMOS	385.00

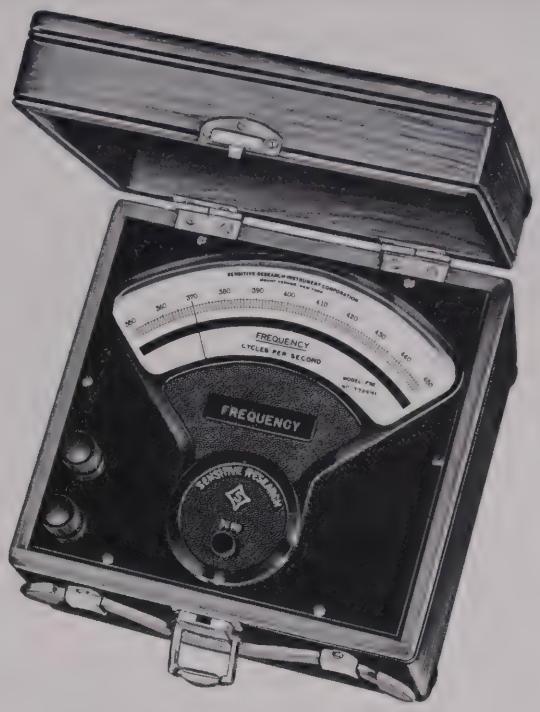
SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY	.25% of center frequency for expanded scale instruments or .25% of full scale for instruments with a measuring range starting at zero frequency.
TYPE	Full wave rectified; permanent magnet, double pivoted moving coil
SCALE	Hand drawn; 6.3"; anti-parallax mirror
POINTER	Knife edge
PERIOD	2 seconds
DAMPING	Induced emf
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
SHIELDING	Electrostatic; magnetic
MAGNETIC SHUNT	Internal; 3% max. adjustment
MECHANICAL ZERO	External zero shifter
CASE	Formica; 7½" x 7¾" x 4¼" h.; bakelite panel; hinged cover; carrying handle
APPROX. WEIGHT	8 lbs. net; 11 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

MODEL FRE



OPTIONAL SPECIFICATIONS

1. Model FRE available with additional self contained voltage ranges up to 400 volts. Ranges are supplied on binding posts. Add $25.00 for each additional voltage range specified. Higher voltage ranges are available but correspondence required.

2. Special instruments are available with any frequency range, provided they are within the limitations set for expanded scale types and the spread of ranges listed below. Correspondence is required.

PANEL INSTRUMENTS

The Model FRE is also available for vertical panel mounting in the deep EW-5A (5" scale length) or EW-7A (7" scale length) edgewise panel case. For dimensions see page 512.

Performance characteristics are the same as listed for the portable type.

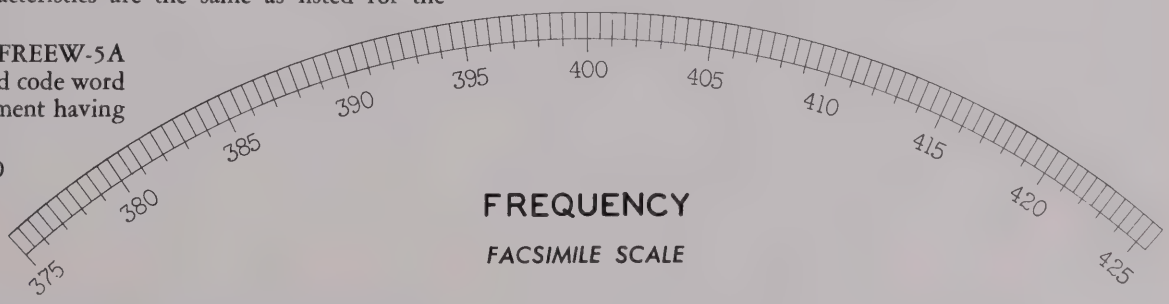
Specify: Model FREEW-5A or FREEW-7A and code word of portable instrument having ranges desired.

Price: Add $30.00 to price of code word selected.

GENERAL DESCRIPTION

The Model FRE is a direct reading electrical indicating instrument for the measurement of frequencies up to 1000 cps. It is available with an expanded scale for reading a narrow frequency span; or with a conventional scale that reads from zero frequency to a full scale value. All instruments are the "zero left" type. Expanded scale instruments have exceptional resolution. Maximum scale spread is ±10% of a specified center frequency.

The instrument consists of a saturable transformer, limiting resistors, rectifiers and a rugged DC instrument as a direct reading indicator. The input voltage whose frequency is to be measured is applied through a limiting resistor to the primary of a saturable transformer. The resultant primary current is sufficient to drive the transformer core material well into saturation on each half cycle, producing constant volt-second pulses in the transformer secondary. A positive and a negative pulse are generated each cycle, and the pulse rate, therefore, is directly proportional to frequency. The positive pulses are passed through a rectifier to an average reading DC instrument to indicate the proper frequency. The negative pulses are fed to a rectifier circuit to provide electrical zero suppression for measuring frequency over a narrow range.



AUDIO FREQUENCY MEASURING INSTRUMENTS

Frequency Ranges in cps	Voltage Range (100Ω/v)	Code	Scale Div.	Price
0 to 100	115 Volts ± 15%	FREAM	100	$450.00
0 to 500		FREBA	100	450.00
0 to 1000		FRECN	100	450.00
54 to 66		FREGT	100	540.00
50 to 70		FREHE	100	540.00
300 to 500		FREDO	100	540.00
350 to 450		FRESI	100	540.00
375 to 425	115 Volts ± 10%	FREXO	100	550.00
750 to 850		FREZA	100	550.00

FORM FACTOR INSTRUMENT

MODEL E

SPECIFICATIONS

AC PORTABLE—HORIZONTAL USE

ACCURACY and FREQUENCY RANGE	Accuracy between 25-500 cps is ± .2% for ratios within 10% of 1.11 and 1.414; ±1% for ratios of 1.1 or higher when measuring Peak/RMS and for ratios of 3.5 or lower when measuring RMS/Average. Accuracy between 500-1000 cycles for the above ratios is ± .3% and ±.2% respectively.
TYPE	A. RMS Indicator: Transformer coupled electrodynamometer.
	B. Ratio Indicator: Rectifier; permanent magnet, double pivoted moving coil.
SCALES	A. RMS Indicator: Uncalibrated; zero and arbitrary full scale points only; anti-parallax mirror.
	B. Ratio Indicator: Peak/RMS and RMS/Average scales; hand drawn; 6.3"; anti-parallax mirror.
POINTER	Knife edge
PERIOD	RMS Indicator, 3 seconds; Ratio Indicator, 1.5 seconds
PIVOTS	Diamond pivoted
JEWELS	Sapphire; spring mounted
RANGE CHANGING	Switch controlled
MAGNETIC SHUNT	Internal; 3% max. adjustment (Ratio Indicator)
MECHANICAL ZERO	External zero shifters
CASE	Oak; 16⅞" x 10¾" x 6¾" h.; cover
APPROX. WEIGHT	26 lbs. net; 45 lbs. shipping

All instruments are provided with data cards listing temperature corrections and maximum overload ratings.

PANEL INSTRUMENTS

The Model E is available in a black bakelite rack panel with instruments mounted in EW-7A (7" scale length) edgewise panel cases. Panel size 19"w × 10½"h. Descriptions of type EW-7A cases on page 512.

Specify: Model EEW-7A. **Price:** $1150.00

GENERAL DESCRIPTION

The Model E is a self-contained combination of two electrical indicating instruments that: (1) shows how much average or peak reading instruments deviate from true RMS indication when used on non-sinusoidal waveforms and (2) gives a correction factor in terms of RMS. Rectifier type instruments which read 1.11 × average value, and most vacuum tube voltmeters which read either 1.11 × average or .707 of peak, give faulty indications when used on non-sinusoidal waveforms. The assumption that the line voltage is sinusoidal is incorrect in many cases, particularly when resonance type regulating transformers are in use. When small motor generators are used there is a tendency to flat top the generated wave. Many devices, particularly those with ferromagnetic cores, operate quite differently when a distorted wave is fed into them.

In those cases where the waveform is non-sinusoidal, but fixed in form, THE FORM FACTOR INSTRUMENT will allow the use of any type of instrumentation desired and immediately derive the correct constant for adjusting the error. This could only be done otherwise by a time consuming harmonic analysis and determination of the phase angle of each harmonic component, and an elaborate mathematical synthesis of the wave components effective value.

The basic circuits of the instruments are shown in Fig. I. A transformer is used in the input for operation at 28, 115,* 220 and 440 volts. It introduces negligible distortion for frequencies well beyond the rated 500 cps. The transformer output is standardized in terms of its RMS value by means of a dynamometer instrument with extended frequency response. The series resistance covers approximately ±15% of the nominal input voltages. By switching circuits, AVERAGE VALUES, POSITIVE PEAKS or NEGATIVE PEAKS can be read on the ratio indicator. The scales are marked in terms of the ratios between RMS and the function designated. This is possible because the RMS value is always standardized to a single red line on the dynamometer scale. If the ratios indicate other than 1.11 and 1.414, corrections can easily be applied to instruments of known type to give accurate readings regardless of the distortion.

Operation is very simple. The control marked "Adjust to Red Line" is turned until the dynamometer reads exactly on the red line at full scale. The ratio instrument can then be read directly for RMS/Average and Peak/RMS values.

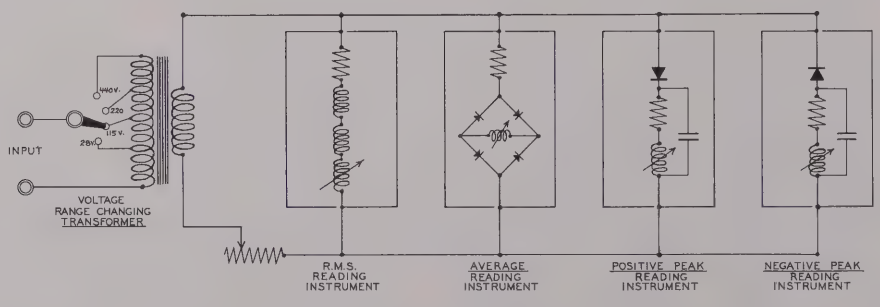


Figure I. Basic Circuits of Model E

Range of Ratios	Code	Price
1.0 to 1.7—Peak/RMS Infinity to 1—RMS/Average	EFFAP	$975.00

* *Direct to input.*

SCALE DRAWING MACHINE FOR ELECTRICAL INDICATING INSTRUMENTS

The Model Scama is a manually operated scale drawing machine for the precision drawing and printing of electrical indicating instrument scales. It is essential equipment for all service stations whose function is the repair and maintenance of electrical and electronic instruments. It is the same scale drawing machine used to draw Sensitive Research scales. By providing placement holes on the main quadrant it can just as easily draw the scales of other commercially available instruments.

Consider the advantages of owning a scale drawing machine like the Model Scama!

1. It is versatile! It can accommodate all flat scale plates from instruments with an angular deflection of 110° or less. A special adaptor is available for circular scale instruments with an angular deflection to 360°. The drawing surface of the scale plate can be either a lacquer finish or paper.

2. Scales can be redrawn to all the accuracy that their resolution will permit! Linear and square law scales can be drawn with equal facility.

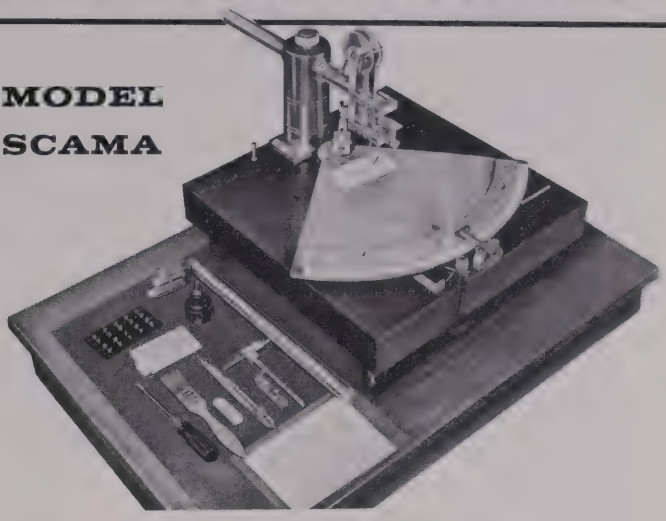
3. Instrument down time is reduced to a minimum! It will seldom be necessary to return an instrument to its original manufacturer. The chance of its being damaged in transit (either way) is eliminated. The average scale can be completely redrawn in one half hour.

4. The price of the Model Scama is small alongside of the economies it will effect! It does away with paperwork, shipping charges and the cost of packaging instruments that must be sent back for repairs. Instruments do not have to be returned to service with calibration curves (which often take longer to draw than a new scale) to be within accuracy. Reading a scale directly is far more accurate and faster than applying corrections for each reading.

5. A service man's valuable time does not have to be wasted! It often takes much longer to try to adjust the linearity of an instrument to match its original scale than it does to repair it.

6. More economical procurement can be made of spare parts! Moving elements can be replaced and their exact scale characteristics easily reproduced. In the case of thermocouple instruments, raw thermocouples can be purchased and installed, eliminating the necessity of stocking specific calibrated thermocouples which cost many times more (and which must be used with correction curves if guaranteed accuracy is to be maintained).

MODEL SCAMA



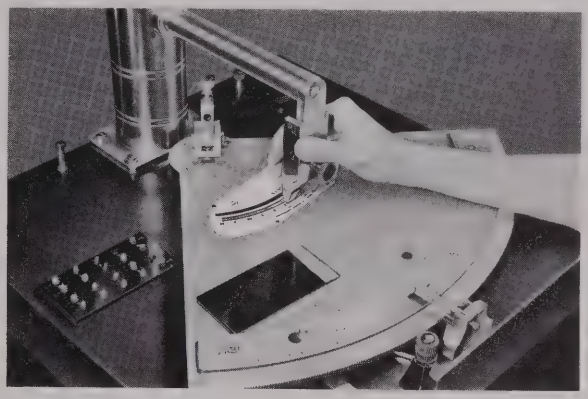
ADDITIONAL SPECIFICATIONS

Furnished with all accessories to completely print and draw a scale including special type, ink, blank scale plates and two sets of operating and maintenance instructions.

A 40 hour course in the use of the machine and a calibration system to employ with it is included at no additional charge.

Shipping Weight: Approx. 200 lbs. **Price:** $3850.00

Dimensions: 21½" x 18" (front to rear)
x 15" (top to bottom)



The photo at left shows the Model SCAMA in operation printing scale numerals.

OPTIONAL FEATURES

1. A series of tapped holes is provided for all Sensitive Research scales. A small clamp is provided for the manual positioning of other scales. If large numbers of a particular type of scale plate are to be drawn regularly a special set of holes may be tapped so that manual positioning will not be necessary. Additional charge $10.00 per set.

2. Special Circular Scale Adaptor

Angular Capacity: Up to 360°

Radial Capacity: Minimum arc 1" radius from scale center
Maximum arc 2½" radius

Scales can be accommodated with a maximum diameter of 4½" and a center hole of no less than ½".

Adaptor must be ordered with the Model Scama. **Price** $394.00.

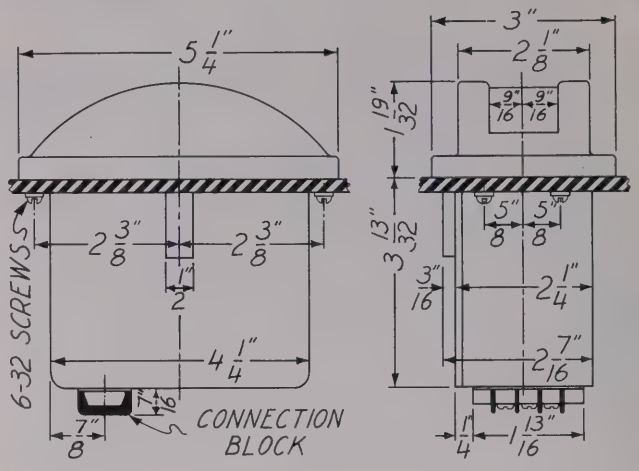
Model Scama and optional equipment are shipped in a returnable container. $50.00 is deducted from the invoice price if it is returned in reusable condition to Sensitive Research.

MOUNTING DIMENSIONS FOR SENSITIVE RESEARCH EDGEWISE PANEL CASES

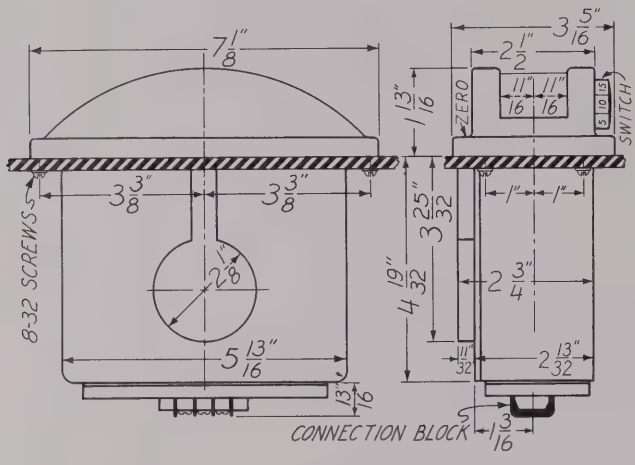
Edgewise panel cases are supplied for flush mounting in a vertical panel. Binding posts or connection lugs are furnished in the rear. Cases are of die cast aluminum with a black wrinkle finish. Switches, when supplied, are as indicated in the drawings. (See individual portable model specifications.) External zero shifters are supplied on the front of all cases.

NOTE

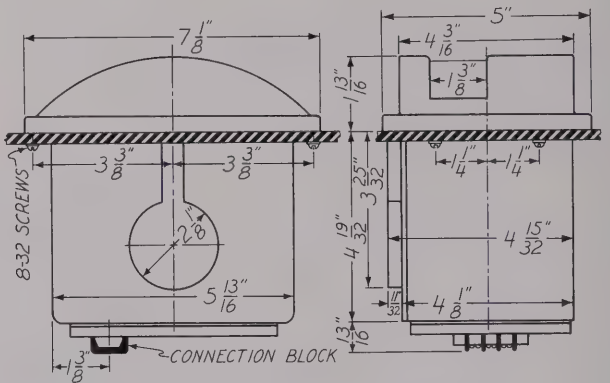
The Types EW-5A and EW-7A replaced the Types EW-5 and EW-7 in May, 1961. There are minor dimensional differences between the two types. For purposes of exact replacement, the types EW-5 or EW-7 can be supplied at no additional charge, **but must be specified at time of ordering.**



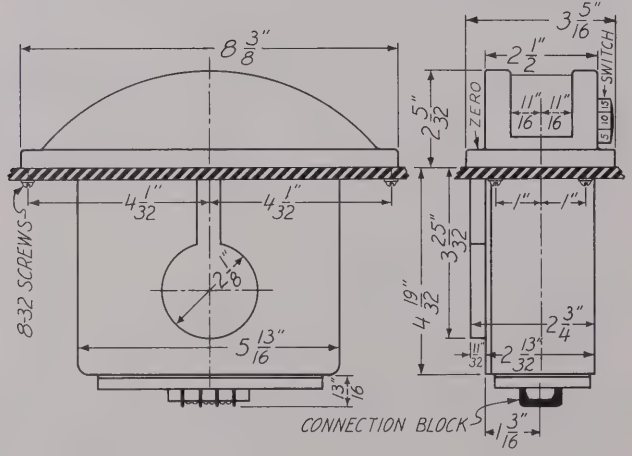
MODEL JDJW-4A CASE, Scale Length 4"



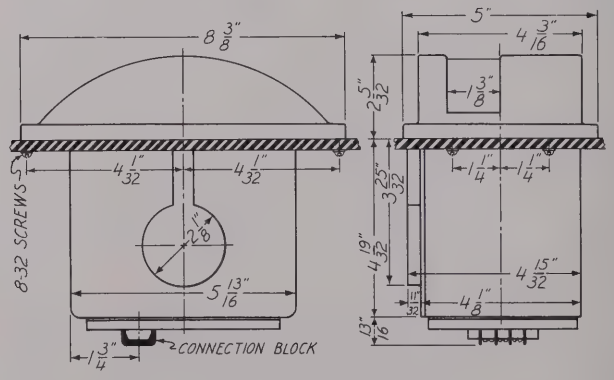
TYPE EW-5A SHALLOW CASE, Scale Length 5"
for Models SD, RA (single range)



TYPE EW-5A DEEP CASE, Scale Length 5"
for Models DYSP, FRE, RA (multirange), SD (switch controlled)



TYPE EW-7A SHALLOW CASE, Scale Length 7"
for Model RA (single range)



TYPE EW-7A DEEP CASE, Scale Length 7"
for Models FRE, RA (multirange)

Prices and specifications subject to change without notice. *Printed in U. S. A.* 75-1

SENSITIVE RESEARCH INSTRUMENT ACCESSORIES

Model	Description	Page
T	Vacuum Thermocouples	601-602
TX	Air Thermocouples	601-602
Type 9145	Low Thermal Switches	602
Type 9630	Dual Contact Copper Switches	602
SH	Current Shunts	603
MUL	Voltage Multipliers	603
TR	Current Transformers	604
STC	Miniature Unsaturated Standard Cells	604

Prices and specifications subject to change without notice. Terms net 30 days F.O.B. New Rochelle, N.Y.

Listed in this brochure are measuring accessories for use in conjunction with electrical indicating instruments or in associated circuits. Their application is cross referenced under "Optional Accessories" in the description of individual instruments listed in other sections of the catalog. Items such as replacement thermocouples, standard cells, power supplies and leather carrying cases, which are specific to a particular instrument or series of instruments, are listed only with the instruments with which they are to be used. Some of these accessories, such as power supplies, may have some general purpose applications in addition to their specific recommended employment. High accuracy, heavy wattage shunts, low thermal choppers and saturated standard cells are listed in the COMMANDER instrument section.

S. STERLING CO.
MANUFACTURER'S REPRESENTATIVE
3300 S. DIXIE DR.
298-7573 DAYTON 39, O. 298-9857

THERMOELEMENTS*

A thermoelement consists of a thermocouple (junction wires) connected thermally and/or electrically to a heater wire (see Figs. 1 & 2). In operation, by applying an AC or DC current through the heater wire of a thermoelement, electrical energy is converted to thermal energy. A small fraction of this energy is converted back to electrical energy at one junction of the thermocouple. This provides a DC output which can be recorded on a DC millivoltmeter or a potentiometer.

All thermocouples can deliver at least 3 mv into a 16 Ω load. When selecting a millivoltmeter for use with a particular thermoelement, the load imposed by the instrument is of primary consideration rather than the open circuit millivolt rating of the thermoelement. Curves taken on a suitable millivoltmeter or a potentiometer can be supplied with each thermoelement. A discussion of thermocouples, and the different types of curves available for various readout devices, is given in Section 7.

Frequency limits listed for all thermoelements are based on AC/DC differences of .5%. The accuracy obtainable in an application is greatly affected by operating techniques.

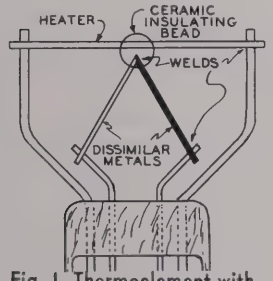


Fig. 1. Thermoelement with isolated junction and heater circuits.

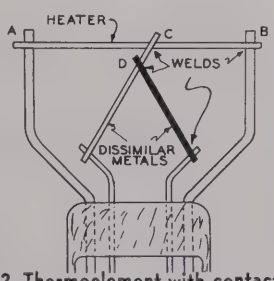


Fig. 2. Thermoelement with contact type junction and heater circuits.

Thermoelements are available in evacuated glass bulbs to eliminate losses due to convection currents (see pg. 602). Normal current ratings from 1 ma to 500 ma can be supplied in converters of this type. Listed on pg. 602 are unmounted and case mounted thermoelements (see photos) of two types. Isolated thermocouples have their junction circuit electrically insulated from their heater wire to minimize the effects of capacitance currents at high frequencies between the junction and DC millivoltmeter used for readout and the rest of the circuit. The junction wires are attached to the heater by a small bead of high melting point material with good thermal conductivity and electrical insulation for 100 v DC. A very small capacitance, created between the isolated circuits, is in series with the capacitance of the instrument (used for readout) to ground or some other parts of the circuit. This interposition of capacitance reduces the currents which otherwise can flow through part of the heater element and cause erroneous readings. Such isolation is, therefore, desirable when low currents have to be measured at a voltage difference considerably off ground.

In general insulated thermoelements have less differences when tested on reversed DC than do contact types. Reversal is smaller than .1% and special units can be provided with a difference of .01% or less.

Contact type thermoelements have their junction and heater circuits in electrical contact with each other. These contacts are welded for current ratings of 5 ma or greater where a metal heater wire is employed. Units with ratings of 2 ma or less use carbon heaters which are cemented to the junction wires. While such thermoelements cannot be constructed as ruggedly as other types, they have the advantage of superior sensitivity and faster response time (as compared to metal heaters) when used for low current measurements. In general, welded contact type thermoelements are slightly more rugged, more sensitive and faster in response than isolated types.

Thermoelements of the contact type are available mounted in air for heavy current measurements. They are cased in bakelite and padded with insulating material for thermal shielding, protection from air currents and physical safeguarding. Listed on pg. 602 are units with normal ratings from 1 amp to 100 amps. DC reversal is in the area of .25%. In these thermoelements the heater and junction circuits are physically placed so that the heater is in a straight line and capacitance and skin effect are reduced to a minimum. Frequency range is, therefore, greatly extended.

**In common usage the term "thermocouple" has been employed interchangeably with the word "thermoelement" although a thermocouple is actually the two junction wires of a thermoelement.*

SENSITIVE RESEARCH INSTRUMENT ACCESSORIES

SPECIAL THERMOELEMENTS

1. Special acorn shaped isolated heater and junction type elements are available for UHF measurements.
2. Units can be supplied in pairs with linearity characteristics matched within .1%.

Correspondence invited concerning special thermoelements.

MODEL T

Unmounted Vacuum Thermoelement.

Case Mounted Vacuum Thermoelement.

MODEL T CONTACT TYPE VACUUM THERMOCOUPLES

Overload Rating 100% max. DC and 7 cps to 10 mc

Normal Milliamps.	Approx. Open Circuit Millivolts	Contact type Max. Heater Resist. (Ω)	Insulated type Max. Heater Resist. (Ω)	UNMOUNTED Code	UNMOUNTED Price	CASE MOUNTED Code	CASE MOUNTED Price
1.0	7	1800	2000	TOSCVP	$50.00	TEBPAP	$65.00
1.5	7	800	1000	TOSENT	40.00	TEBONY	55.00
2	7	750	800	TOSALT	35.00	TEMPIR	50.00
5	7	75	80	TODZRR	30.00	TELAMG	45.00
7	7	45	45	TOHARA	30.00	TEVERT	45.00
7.5	7	40	40	TOGAIL	30.00	TEZZIN	45.00
10	7	20	20	TOLASP	30.00	TENORT	45.00
15	7	14	14	TOCOLT	30.00	TELERT	45.00
20	7	10	10	TOSURF	30.00	TEKEST	45.00
25	7	7	7	TOSAND	30.00	TELFRO	45.00
50	7.5	5	5	TOSAID	30.00	TEBALT	45.00
100	7.5	2	2	TOCASE	30.00	TESOFT	45.00
150	7.5	1.5	1.5	TOCEAN	30.00	TEMAID	45.00
250	7.5	.6	.6	TOFTEN	30.00	TECANT	45.00
500	7.5	.4	.4	TOSTAM	30.00	TESACT	45.00

MODEL T INSULATED TYPE VACUUM THERMOCOUPLES

Overload Rating 100% max.
DC and 7 cps to 10 mc

Any contact type thermocouple is available with electrically isolated heater and junction circuits. Specify: Model T and code word for contact type plus the suffix "-S". **Price:** Add $8.00 to the price of the equivalent contact type. (Example: 1 ma unmounted thermoelement Code TOSCVP-S, price $58.00.)

MODEL TX MOUNTED AIR THERMOCOUPLES

Overload Rating 50% max.
DC and 7 cps to 20 mc

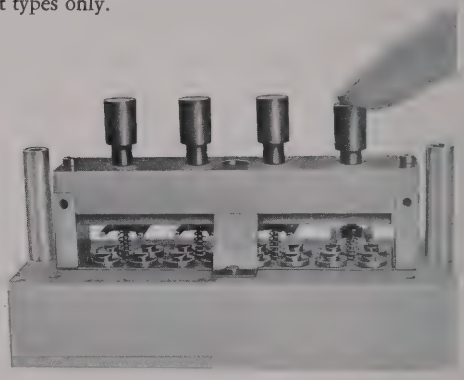
Range	Code	Price	Range	Code	Price
1 amp	TXARO	$53.00	20 amps	TXUBY	$70.00
2 amps	TXEAM	53.00	30 amps	TXOOG	78.00
5 amps	TXILE	53.00	50 amps	TXOHR	100.00
10 amps	TXEZI	59.00	100 amps	TXAMP	225.00

Note: Air thermocouples are available as contact types only.

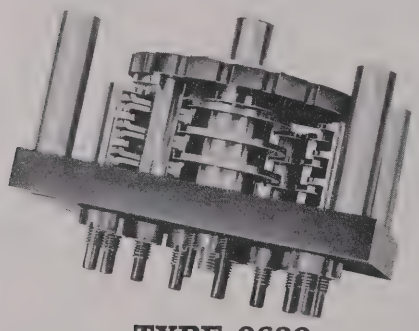
LOW THERMAL SWITCHES

***The Commander Type 9145 Low Thermal Selector Switch** is intended for use in potentiometer or other circuits where the generation of stray emfs must be kept to an absolute minimum. Its construction to a design by Dr. T. M. Dauphinee of the National Research Council in Canada assures a positive circuit connection by the use of self-wiping contacts while the generation of thermal emfs under all possible conditions is limited to less than 0.01 μv. The switch contains 4 DPST sections that are enclosed in a solid block of aluminum to minimize temperature gradients. Any one of 4 circuits can be selected by merely depressing a push button. The buttons lock down and release when any other button is depressed. Two or more buttons may be simultaneously locked if desired. A separate release button is provided to open all circuits. The terminals can be cross connected for applications requiring a reversing switch.

Specify: Type 9145. **Price:** $343.00.



TYPE 9145
with panel & case removed



TYPE 9630
Dual Contact Switch (3 brush type shown)

***Commander Dual Contact Copper Switches.** Standard self-wiping dual contact switches are available for transfer and/or reversing applications demanding the highest degree of precision. The complete wiper or brush is made up of two assemblies, each with 8 individually sprung contact arms that are separated and riveted together at the center. The elasticity of the wiper arms maintains the whole assembly against the inner surfaces of the center segments of the brush and the stationary contacts. This allows the wiper to "float" between the stationary contacts since it is not mechanically held in place other than by the pressure of its own individually sprung arms. Hence, contact pressure and contact resistance is always constant. The generation of thermal emfs can be kept as low as .01 μv. For exceptionally low resistance applications, the wiper assemblies can be paralleled. Switches have a resistance as low as 100 microhms between soldering points and will vary less than 10 microhms between contact points. *Inquiries are invited covering special switches.*

PRICES: DUAL CONTACT SWITCHES	Poles	5/16" Stud Diam. Base Price 2 Pos.	5/16" Stud Diam. Add. Price Per Pos.	5/16" Stud Diam. Max. Poss. Pos.	3/8" Stud Diam. Base Price 2 Pos.	3/8" Stud Diam. Add. Price Per Pos.	3/8" Stud Diam. Max. Poss. Pos.	1/2" Stud Diam. Base Price 2 Pos.	1/2" Stud Diam. Add. Price Per Pos.	1/2" Stud Diam. Max. Poss. Pos.
SINGLE BRUSH	1	$ 63	$ 1	25	$ 67	$ 1.50	25	$ 73	$ 2	16
	2	81	2.50	12	83	4	12	85	6	6
	3	95	10	7	98	14	6	104	8	3
	4	106	15	4	126	17	4	147	—	—
DOUBLE BRUSH	1				$ 77	$ 2	25	$ 80	$ 3	16
	2				95	5	12	97	9	6
	3				113	16	6	116	16	3
	4				146	21	4	168	—	—
TRIPLE BRUSH	1							$256	$ 7	11

Specify: Dual Contact Copper Switch. State number of brushes, number of poles and diameter stud required.

*Commander products are manufactured for SRIC by Guildline Instruments, Ltd. in Smiths Falls, Canada. F.O.B. point is Rouses Point, N. Y. Prices include customs duty, brokerage, packaging, conversion to American dollars and all other special handling charges.

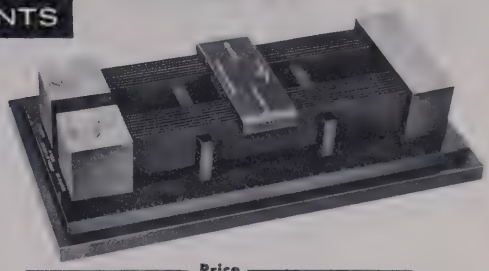
MODEL SH LABORATORY STANDARD CURRENT SHUNTS

Listed right are 4 terminal heavy current shunts designed for continuous duty within rated accuracy. The shunts utilize manganin strips as their resistance material. The strips are imbedded in heavy brass blocks and mounted on a thick, flat bakelite base. The entire assembly is aged to provide the long term stability required of a laboratory standard.

Normal accuracy is .1%. Accuracies of .05% can be provided for shunts with ratings up to and including 50 amps at an additional cost of 50% over list price. Special shunts are available but correspondence required.

When shunts are purchased at the same time as a millivoltmeter they can be calibrated together to be within the accuracy of the instrument. In the selection of a millivoltmeter for use with current shunts, consideration must be given to its power consumption. A low sensitivity instrument can draw current sufficient to cause erroneous readings. For maximum accuracy therefore, shunts of 20 amps or less must be adjusted with the millivoltmeter with which they are to be used.

MODEL SH



Range in amps	Price 50 mv	100 mv	300 mv
1	$44.00	$56.00	$112.00
2	44.00	56.00	112.00
3	48.00	60.00	120.00
5	68.00	84.00	168.00
10	80.00	100.00	200.00
15	88.00	108.00	216.00
20	92.00	116.00	232.00
30	100.00	128.00	256.00
50	112.00	140.00	280.00
75	116.00	145.00	290.00
100	124.00	156.00	312.00
150	136.00	168.00	—
200	144.00	180.00	—
300	168.00	210.00	—
500	204.00	256.00	—
1000	280.00	—	—

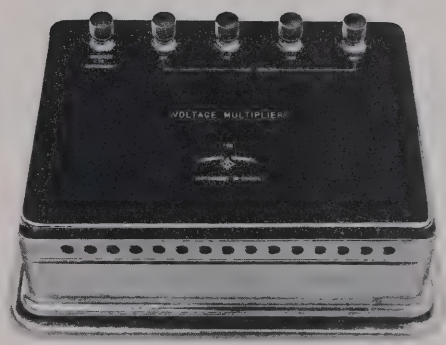
MODEL MUL LABORATORY STANDARD VOLTAGE MULTIPLIERS

MODEL MUL

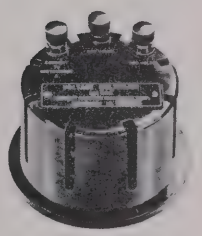
Multipliers are available to extend the range of voltmeters, or to be placed in series with microammeters or milliammeters to create voltage ranges. All resistances are wound non-inductively on ceramic bobbins and aged to provide a strain free mounting. Low temperature coefficient wire such as manganin and evanohm is used as the resistance material. Cases vary in size depending on the total value of resistance, watt dissipation and number of bobbins that have to be mounted. All multiplier cases (except the Type A which is of bakelite) are made of walnut.

Multiplier values must be selected to include the resistance of the instrument range with which it goes in series. Multiranges can be tapped off for any multiplier at an additional cost per range as follows:

Case Type	Dimensions	Price per additional range
A	4⅛" diam.—3¼" height	$15.00
B	10³⁄₁₆" x 5⁵⁄₁₆" x 5" h	25.00
CV	12" x 9" x 7⁵⁄₁₆" h	30.00
E	16¼" x 11¾" x 9⅜" h	30.00
BSC	23½" x 14⅜" x 8¾" h	30.00



Type E Voltage Multiplier



Type A
Voltage Multiplier

Normal accuracy is .1%. At a 50% surcharge an accuracy of .05% can be furnished for values up to 1000 v. When multipliers are ordered at the same time as the instrument with which they are to be used, they can be furnished within the accuracy of the instrument.

Range Extension in Volts	100 Ω/v Price	Case	500 Ω/v Price	Case	1000 Ω/v Price	Case	5000 Ω/v Price	Case	10,000 Ω/v Price	Case
100	$29.50	A	$29.50	A	$29.50	A	$32.50	A	$ 36.00	A
200	34.00	A	29.50	A	30.50	A	36.00	A	43.50	A
500	47.50	A	34.50	A	36.00	A	52.00	A	97.00	A
1000	85.00	B	40.00	A	44.50	A	80.50	A	145.50	A
1500	142.50	CV	47.50	A	55.00	A	92.50	A	208.00	B
2000	165.00	CV	55.00	A	64.00	A	135.00	A	225.00	B
3000	225.00	E	80.00	B	92.00	B	188.00	B	362.00	CV
5000	375.00	BSC	92.00	B	137.50	B	352.00	B	575.00	CV
10000	575.00	BSC	224.00	CV	264.50	CV	611.50	CV	1275.00	CV

MODEL TR CURRENT TRANSFORMERS

MODEL TR

The Model TR, Types 1 & 2, are current transformers to extend the ranges of AC indicating instruments. The Type 1 is mainly for use with ammeters having a burden lower than 5 va. The Type 2 has lower phase angle errors and an allowable 15 va loading and, therefore, is designed for use with wattmeters and with ammeters having a relatively high burden. By providing a 5 to 5 ratio, both transformers can be self checked.

THE SELECTION OF CURRENT TRANSFORMERS

The extension of AC instrument ranges by the addition of current transformers has advantages as follows: **1.** Accuracies obtainable are comparable to the rated tolerances of the instruments. **2.** No additional losses are involved and hence power consumption is only slightly increased regardless of how great the range extension. **3.** Transformers are the most compact devices that can be used to provide additional ranges and to enable high current measurements.

In operation, a current transformer can be considered, for practical purposes, as any transformer feeding into a short circuit. If the transformer's losses are negligible, its primary and secondary ampere turns are equal. If a low burden ammeter is the secondary short, then its reading is equal to the reciprocal of the turns ratio times the current in the primary of the transformer, and the instrument can be calibrated in terms of this primary current.

Standard current transformers have 5 ampere secondaries and operate from 20% to 120% of rated current within guaranteed accuracies. (Rated current is that primary current which gives a 5 ampere secondary current.) Full accuracy of the transformer, therefore, is maintained only for secondary currents of 1 ampere through 6 amperes.

The allowable load for any transformer is stated in terms of volt-ampere burden and this value must not be exceeded or additional errors can result. Type 1 transformers are recommended for use with ammeters, excepting when the higher allowable burden of the Type 2 is required.

When a wattmeter is to be used with current transformers, accuracy is affected by one other factor. In operation, the secondary current has a slight phase shift due to losses in the transformer. The wattmeter, therefore, has a current supplied to its field circuit which is not exactly in phase with the transformer's primary current (which is the actual load current). Type 2 transformers are specially made to reduce these errors to negligible values and are recommended for wattmeter circuits.

In selecting transformers, current ratings, burdens and allowable phase angle errors must be carefully considered when they are to be employed in conjunction with low power factor wattmeters. Such wattmeters operate over a wide range of current from well below normal rating to five times this figure for 20% power factor instruments. Wattmeter ranges must be selected purely on the basis of "current being drawn" and the watt ranges taken as they fall from the product of current and voltage. The ranges of the Model TR transformers allow for simplified range multiplication factors.

As an example of the preceding discussion: Suppose a load of 100 amps, 100 v, 20% PF is required to be read on a wattmeter. The secondary current of the Type 2 transformer is 5 amps, hence select a wattmeter with the following specifications: (1) 20% PF, (2) normal current 1 amp, max. current, 5 amps, (3) 100 v normal potential circuit rating, (4) 100 watts full scale. The transformer must be selected on the basis of current being drawn only. A Type 2 can be used on its 100 amp range to give 5 amps to the field circuit of the wattmeter. This gives the transformer-wattmeter combination a range of 0-2000 watts by virtue of the 100-5 step down ratio. In another case, where the power factor of the load is close to unity, select a wattmeter of the 50% PF type, whose NORMAL current ratings are approximately equal to, or slightly greater than, the transformer secondary current. This yields maximum accuracy since the transformer is still operating closer to 100% of rated current, than to its lower limit of 20%.

SPECIFICATIONS

PRIMARY RANGES	Inserted primary—800/400/200 amps Wound primaries—100/50/20/10/5 amps
SECONDARY	5 amps
FREQUENCY	25 cps to 500 cps
RATED LOAD CAPACITY	**TYPE 1:** 5 va max. **TYPE 2:** 15 va max.
DESIGN BURDEN	**TYPE 1:** 5 va at .9 PF **TYPE 2:** 15 va at .9 PF
RATIO ACCURACY	**TYPE 1:** ±.25% ratio accuracy for currents of 20% to 120% of rated current at frequencies of 50 cps to 500 cps with a 0-5 va .9 PF secondary load. **TYPE 2:** ±.15% on ratio and ± 2′ lagging PF or 10′ leading PF from 20% to 120% of rated current at frequencies of 50 cps to 500 cps with a 0-15 va .9 PF secondary load.
INSULATION	Insulated for operation on 2500 v circuits. Test voltage, secondary to wound and inserted primary 10,000 v
WINDOW	2⅜" diam.
CASE	Cast epoxy with fold down handle; size 6⅝" x 6⅝" x 3¾"
APPROX. WEIGHT	9 lbs. net; 15 lbs. shipping

SPECIFY: Model TR **PRICE:** Type 1: $114.00, Type 2: $140.00

MODEL STC UNSATURATED MINIATURE STANDARD CELL

Miniature unsaturated cadmium standard cells are available (mounted or unmounted) with Sensitive Research Certificates having direct traceability to NBS. Accuracy is ±.025% of stated emf. Size, unmounted, is 1" W x 3" L; mounted it is 3¼" diam. x 3" high. Temperature coefficient is —.00001 v/°C. Internal resistance is below 1200 Ω.

Volts	Type	Code	Price
1.0188 to 1.0198	Unmounted	STCUM	$20.00
	Mounted	STCOD	30.00

For information on Model STC replacement standard cells for Models THACH and BS-1 see section 1, pages 64-65.

Short Form COMMANDER INSTRUMENT CATALOG

A BROCHURE OF ELECTRICAL MEASURING STANDARDS

S. STERLING CO.
Manufacturers' Representatives
SOUTH BYRON
SYRACUSE 10, N.Y.

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COMMANDER instruments are manufactured for Sensitive Research by Guildline Instruments, Ltd. of Smith Falls, Ontario. Prices include customs duty, brokerage, packaging, conversion to American dollars and all other special handling charges. Prices and specifications are subject to change without notice.

EXEMPTION FROM BUY AMERICAN ACT

All COMMANDER instruments are of Canadian origin and come under Federal Class Code 6625. In accordance with ASPR 6-103 and 6-104, the Buy American Act restriction for military procurement is waived, and COMMANDER instruments are considered as United States equipment.

DUTY FREE ENTRY OF COMMANDER INSTRUMENTS

Duty free certificates can be obtained for COMMANDER instruments in accordance with ASPR 6-605 (Revised Oct. 1, 1959). Where the material requisitioned is for purposes of National Defense, duty free entry can be accorded Canadian supplies upon proper application of the cognizant contracting governmental agency.

Duty Free Certificates cannot be issued where the duty is less than $50.00.

DUTY FREE PRICES

Special quotations will be given in those cases where a duty free certificate is applicable.

WARRANTY

Potentiometers, Bridges, Volt Ratio Boxes and Standard Resistors are warranted for five years, all other models for one year.

CERTIFICATION BY NBS OR NRC

COMMANDER instruments may be forwarded for certification to either the National Bureau of Standards in Washington, D. C., or Boulder, Colorado, or the National Research Council in Ottawa, Canada. In the case of NBS, it is preferable that purchase orders for such services be made out directly to that organization. Quotations can be issued by Sensitive Research to cover all testing accomplished by NRC.

ORDERING INFORMATION

Orders should be made out to Sensitive Research Instrument Corporation, 310 Main St., New Rochelle, N. Y. Terms: Net 30 days. F.O.B.: Rouses Point, N. Y. (except as specifically noted).

S *Symbol of Quality*

SENSITIVE RESEARCH
INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *Electrical Measuring Instruments Since 1927*

POTENTIOMETERS

The following table gives brief specifications for all COMMANDER potentiometers. Complete descriptions for each type are given on this and the following pages.

Type	Significant Figures (Below 1 volt)	Range Factor	Ranges	Resolution	Accuracy in % of Reading	Price
9144	6	X1	−10 μv to 2.101010 V	1.0 μv/step	± (.001% + 0.5 μv)	$5934.00
		X0.1	−1 μv to 0.2101010 V	0.1 μv/step	± (.001% + 0.1 μv)	
9120	7	X1 only	0 to 2.0999999 V	0.1 μv/step	± (.0015% + 0.1 μv)	$4115.00
4363D	6	X1	−15 μv to 1.901010 V	1.0 μv/step	± (.0015% + 1 μv)	$3133.00
		X0.1	−1.5 μv to 0.1901010 V	0.1 μv/step	± (.0015% + 0.5 μv)	
9180	5	X1	−10 μv to 2.10100 V	10 μv/step	± (0.002% + 1 μv)	$2366.00
		X0.1	−1 μv to 0.210100 V	1 μv/step	± (0.002% + 0.5 μv)	
		X0.01	−0.1 μv to 0.0210100 V	0.1 μv/step	± (0.002% + 0.1 μv)	
	Optional Range ➤	X0.001	−0.01 μv to 0.00210100 V	0.01 μv/step	± (0.002% + 0.05 μv)	$2554.00
9174	4	X1	−0.1 μv to 1010 μv	0.1 μv/step	± (0.01% + 0.5 μv)	$2023.00
		X0.1	−0.01μv to 101 μv	0.01 μv/step	± (0.01% + 0.5 μv)	

DAUPHINEE POTENTIOMETER TYPE 9144

The Type 9144 is a 4 dial, 6 figure DC vernier Potentiometer with an *accuracy of at least 3X that of similar commercially available equipment.* Internal quality control demands that the linearity be initially adjusted to better than 2 ppm. Stability is guaranteed to be better than 1.5 ppm per year. The instrument is remarkable in the unique precautions that have been taken in the design to reduce the importance of the contact resistance of all emf dials to a position of minor significance. In addition to being a superb measuring potentiometer it is:

1. A Resistance Comparator to an accuracy of ± 2 ppm (.0002%). Deviations of ± 50 ppm in the standard resistor used can be dialed into the potentiometer, and therefore the unknown resistor can be compared against the certificated value of the standard resistor directly without requiring corrections or computations.
2. A Saturated Standard Cell Comparator that will detect differences of ± 1 μv.
3. A .01% accurate variable 4 Terminal Standard Resistor.
4. A Standard Cell Enclosure internally air thermostatted at 28°C and containing a bank of two ± .001% accurate Type 4305 Saturated Standard Cells.

The Type 9144 Potentiometer is based on an original design by Dr. T. M. Dauphinee of Canada's National Research Council. All rights to the design are protected by a United States Patent application.

TYPE 9144
Price $5934.00 (2 range)
Price 6134.00 (3 range)

SPECIFICATIONS

ACCURACY: X1 Range ± (.001% of reading + .5 μv)
X0.1 Range ± (.001% of reading + .1 μv)

RANGES: X1 Range 2.101010 V.; X0.1 Range 0.2101010 V
The third dial has an additional negative step of 10 μv. Ranges are switch controlled. (X.01 range optional)

RESOLUTION: Reads in increments of 1 μv on X1 range and 0.1 μv on X0.1 range.

STANDARD CELL CIRCUITS: Range is from 1.017500 V to 1.020100 V adjustable to ±1 μv. Separate switch positions are provided for connection to either internal standard cell or one external standard cell.

GALVANOMETER CIRCUITS: A separate galvanometer circuit is provided for the monitoring of the standard cell emf while making potentiometric measurements. Each circuit has a 4 position (Lo, M, Hi, and Reverse), low thermal emf (less than .01 μv), push button sensitivity switch with self wiping brush contacts. The potentiometer input resistance varies from 35 Ω at zero to 150 Ω at maximum setting. Recommended galvanometer is Type SR 21 in conjunction with Photocell Amplifier Type 5214.

BATTERY CIRCUIT: A 6 V battery is required. The current drain is 20 ma for all settings. 3 decade dials and 2 continuously variable shunted resistors enable the user to adjust the battery current to better than 1 ppm.

THERMAL EMFs: Residual thermal emfs less than .1 μv.

READOUT: Directly on 4 dials; 20 steps of .1 V, 100 steps of .001 V, 100 steps of .00001 V, 10 steps of .000001 V. *No slide wire with its attendant inaccuracy and maintenance problems.* Every switch step is an individually calibrated position.

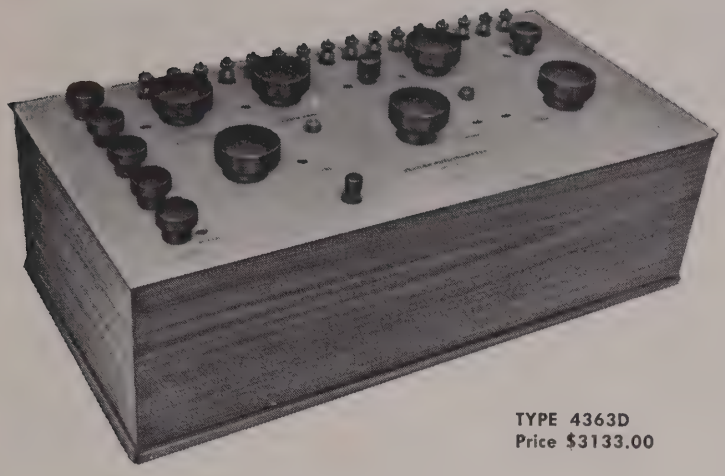
CERTIFICATION: Completely "Self Checking." There is no more accurate way of certifying the potentiometer.

GENERAL: Switch contacts and all terminals are made of copper for thermal free operation. Design and construction of switches is unique, and assures long life and a minimum of maintenance. Instrument is mounted in a metal lined box and paneled externally with a walnut grained formica for maximum durability and resistance to humidity and dust. Special attention is given to guarding and shielding. Case size is 24½" x 14½" x 9" high. Weight is approx. 60 lbs.

TEMPERATURE MEASURING ACCESSORY

An accessory to the Type 9144 Potentiometer is available to permit temperature measurements over a range of −200°C to +700°C at an accuracy of ± (0.001C° + 0.001C° per hundred degrees) utilizing a standard 25 Ω platinum resistance thermometer. The resistance measuring range of the combined equipment is from 0 to 105 Ω with a resolution of 50 microhms per step of dial 4 (0.0005C°). Prices and specifications upon application. (Accuracy statement does not include the possible error of the thermometer.)

POTENTIOMETERS



TYPE 4363D
Price $3133.00

DC POTENTIOMETER TYPE 4363D

The Type 4363D is a 4 dial, 6 figure DC vernier Potentiometer. Although more economical in cost than the Type 9144, it is nearly its equal in precision and accuracy. The instrument does not have a slidewire and therefore the attendant inaccuracy and stability difficulties that are associated with such a component part are non-existent. Each switch position on the main dials is an individually calibrated point.

RANGE POSITION	MEASURING RANGE	RESOLUTION	THERMAL EMFs MAX.	ACCURACY
X1	−15 μv to +1.901010 V	1 μv	0.5 μv	±(.0015% + 1 μv)
X0.1	−1.5 μv to +0.1901010 V	0.1 μv	0.5 μv	±(.0015% + 0.5 μv)

Internal quality control demands that the linearity be initially adjusted to better than 3 ppm. Stability is guaranteed to better than 1.5 ppm per year. A 5 position copper selector switch connects the potentiometer to the standard cell circuit or any one of 4 pairs of copper measuring terminals. A 2 position plug selects either the X1 or the X0.1 range. The standard cell circuit has a range of 1.01806 V to 1.01846 V in 20 steps of 20 μv. Provision can be made for other standard cell values and finer adjustment if necessary. A 2 V battery is required and the current drain is approx. 20 ma. 4 decade dials and a continuously variable shunted resistor enable the user to adjust the battery current to better than 1 ppm. Resistance of the instrument changes from approx. 1 Ω at zero to 90 Ω at maximum setting. A lock-down galvanometer press key operates in conjunction with a 4 position sensitivity switch. The galvanometer recommended for use with it is the Type 4500/SR4 with a 10 Ω coil resistance or the Type SR21 and Type 5214 Photocell Galvanometer Amplifier. Case is of formica. Size is 27″ x 12½″ x 7½″ high. Weight is approx. 56 lbs.

Additional potentiometers are listed on pages 11-9 and 11-10.

BRIDGES

THERMOMETER BRIDGE TYPE 9500

The Type 9500 Direct Reading Resistance Thermometer Bridge was first produced in 1957 for the National Research Council in Ottawa, Canada, in accordance with a design by their Drs. T. M. Dauphinee and H. Preston-Thomas. So successful was the operation of this equipment that the full details were published in the March 1960 issue of Review of Scientific Instruments. Reprints of the complete paper may be obtained on request.

The bridge has wide application, when used with a recorder, in the calibration of thermocouples, liquid in glass thermometers and some types of resistance thermometers – and when used with a thermometer and null indicator, in the determination of spot temperature. Measurements in most cases can be made into a one-man operation. It largely replaces slow and cumbersome equipment such as the Smith and Mueller Bridges or other systems such as may be set up with a potentiometer and resistor.

The Type 9500 is a six dial resistance thermometer bridge that reads directly in degrees centigrade. *It is not necessary to convert resistance readings to temperature readings.* By using any standard 25.5 Ω platinum resistance thermometer as a sensing element, the bridge subdivides the temperature scale in increments of 0.001°C from −50°C to +711.110°C with an accuracy (exclusive of that of the thermometer) of ±0.001%. Particular attention has been paid in the design to eliminate errors due to internal emfs and contact resistances.

The instrument includes a voltage comparator network by which the potential across the bridge resistors can be continuously compared with the potential across the thermometer element when the two are connected in series with the supply battery. The comparison is by a potentiometric method and is completely independent of current and potential lead resistances of the thermometer. The thermometer can therefore be located at a point remote from the bridge without affecting measurement accuracy. All important resistors in the measuring circuit are enclosed in an aluminum block which is thermostatically controlled at 28°C. The instrument can be checked

TYPE 9500
Price $7641.00

by conventional autocalibration procedures. Power required is 110 V, 60 cps. The only external equipment necessary is a sensitive null detector. A chart recorder can be used to indicate graphically the reading of the lower three dials. This facility is made possible by the inclusion of a circuit which automatically adjusts the bridge and thermometer current so that over the full range of the temperature dials the output in volts per degree is constant and the deflectional sensitivity of the recorder is therefore also constant. The output of the bridge is .2 mv/°C. Case is of formica. Size is 28″ x 15¾″ x 12″ high. Weight is approx. 80 lbs.

VOLT RATIO BOXES

*STANDARD VOLT RATIO BOX TYPES 9700 and 9700A**

The Type 9700 Standard Volt Ratio Box series is constructed to a design based on that used at the National Bureau of Standards and as described in NBS Research Paper RP 1419. *An instrument of this type is absolutely necessary for the high accuracy measurement of voltages above that of the normal range of potentiometers.* The design reduces to a minimum the two principal sources of errors in volt ratio boxes which are (1) unequal self-heating of the voltage divider chain and (2) insulation surface leakage. The instrument is self-contained in a thermostated oil bath. Oil is circulated by a motor driven impeller. Additional specifications are as follows:

RANGES: .15/.3/.45/.6/.75/1.5/3/4.5/6/7.5/15/30/45/60/75/150/300/450/600/750 V

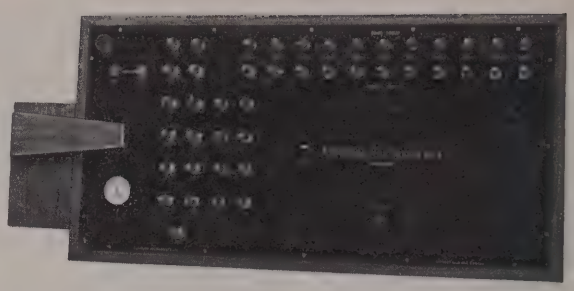
* (Type 9700A contains additional taps at 900/1050/1200/1350/1500 V constructed to the same specifications)

ACCURACY: ± .001% on initial adjustment. ± .005% or better over a 5 year period

STABILITY: ± 10 ppm or better per year

RESISTANCE: 333⅓ ohms/volt

SELF-HEATING: Total power dissipation of the working circuit is only 2.25 watts (4.5 watts in 9700A) in a temperature controlled oil bath.



TYPE 9700 **Price $3814.00** **TYPE 9700A** **Price $4456.00**

SURFACE LEAKAGE: A second voltage divider chain is connected in parallel with the working potential divider and tapped at appropriate points to provide a series of guard potentials. Leakage paths are not subjected to more than 75 V and do not shunt resistance sections greater than 25,000 Ω.

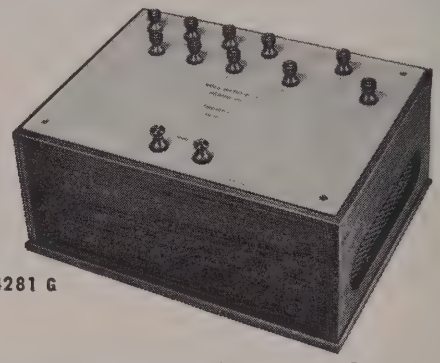
Case is of formica. Size is 25″ x 17″ x 9″ high. Weight is 100 lbs. (9700A is 36″ x 19″ x 12″ high. Weight is 160 lbs.). Supplied with white mineral oil in returnable 5 gal. cans.

STANDARD VOLT RATIO BOX TYPE 4281 SERIES

The Type 4281 Volt Ratio Box Series covers ranges of up to 1500 V in various combinations. Ratio accuracy is guaranteed to be better than ± .01%. Output is 1.5 V for maximum rated input. Resistance in all cases is 100 Ω/v. Other resistance values and units with a 1 V output for rated input can be procured on special order.

TYPE	RANGES (VOLT TAPS)	PRICE
4281A	15/30/75/150/300/750	$315.00
4281B	15/30/75/150/300/600	315.00
4281C	150/300/600	239.00
4281D	15/30/75/150/300	239.00
4281E	15/30/150/300	239.00
4281F	150/300	203.00
4281G	30/75/150/300/600/750/900/1200/1500	427.00

The input terminals are also marked with multiplication factors with respect to the output terminals, which is a very useful feature. Using the Type 4281A as an example, a ratio of X2 can be obtained if the input is applied to the 30 V tap and the output is taken from the 15 V tap. This same technique can be utilized between all taps, and is an excellent way of increasing the resistance of the load applied to the measured source. The volt ratio boxes can be used for inputs of less than 15 V in conjunction with the X0.1 range of the potentiometer — without loss of resolution. As an example, when 3 V are applied to the 30 V input terminals the output is 0.15 V.



TYPE 4281 G

Case is of formica. Maximum size (dependent on ranges) is 15¼″ x 11¾″ x 7 11/16″ high. Maximum weight is 19 lbs.

CONSTANT TEMPERATURE ENCLOSURES

CONSTANT TEMPERATURE STANDARD CELL ENCLOSURE TYPE 9152

The Type 9152 Constant Temperature Standard Cell Enclosure accommodates four Type 4305 saturated standard cells and maintains a nominal internal temperature of 28° to 36° as required with a maximum variation of ± 0.01°C. The cells are fixed to a mounting plate which slides into the inner of two aluminum cylinders. This cylinder is contained in and thermally insulated from a larger aluminum cylinder on the outside of which is wound an electrical heating element. Temperature changes are detected by a mercury-in-glass thermostat which operates a transistor switch and controls the heater current. The outer cylinder is heavily thermally lagged. In addition, a self-contained thermistor bridge serves as an internal temperature sensing element. If the bridge is connected to a 1.5 V dry cell and a galvanometer, the temperature stability can be checked to within ± .001°C by galvanometer deflection in conjunction with a continuously variable calibrated dial that is mounted on the front panel. The dial has a 12 division scale with a value of 0.01C°/division. Enclosure is air thermostatted.

The unit operates from a 110V/60 cps supply and is fitted with terminals for the connection of a 12 V standby lead acid battery. Change-over from 110 V to 12 V operation is automatic on failure of the AC supply. Automatically protected from overheating.

Case is of formica. Size is 12″ x 12″ x 18″ long. Weight is approx. 30 lbs. Type 9152A accommodates up to 12 cells. Unless otherwise specified enclosures are adjusted to 28°C operation.

TYPE	Price
9152 (includes 4 cells)	$ 979.00
9152A (includes 12 cells)	$1557.00
9152P (See page 11-11.)	

STANDARD RESISTORS

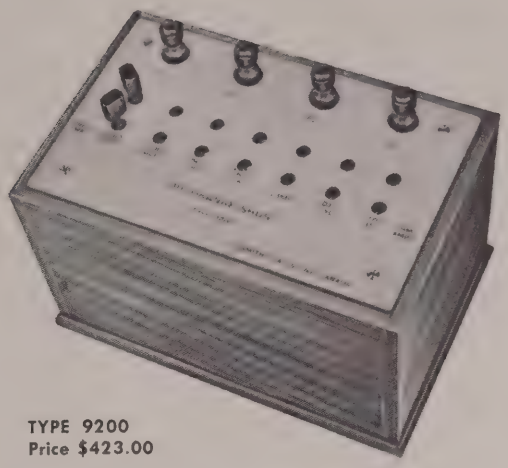
MULTIPLE STANDARD RESISTOR TYPE 9200

The Type 9200 is a ±.01% accurate Multiple Standard Resistor intended for the potentiometric measurement of direct currents from 0-15 amperes. Seven 4 terminal resistors are enclosed in a single compact unit with one set of current and potential terminals and two plugs for the selection of the required resistance value. The unit is designed for use with a potentiometer reading up to 0.15 V with a resolution of 1 μv. Stability is guaranteed to be better than 20 ppm/year. Case is of formica. Size is 11″ x 7″ x 7½″ high. Weight is 12 lbs.

Resistance values with maximum watt ratings are as follows:

Resistance (ohms)	Watt Rating	Current Range
10,000	0.5	0 — 15μa
1,000	0.5	15μa — 150μa
100	0.5	150μa — 1.5ma
10	0.5	1.5ma — 15ma
1	0.5	15ma — 150ma
0.1	1.0	150ma — 1.5a
0.01	2.25	1.5a — 15a

Resistors are adjusted to give an accuracy of ±0.01% at any current value shown above.



TYPE 9200
Price $423.00

Special Multiple Standard Resistors are available. Correspondence invited.

4 TERMINAL STANDARD RESISTORS TYPES 1659, 1682, 3111

TYPE	PRICE
1659	$154.00
1682	273.00
3111	445.00

The 4 Terminal Standard Resistors Types 1659, 1682 and 3111 with power ratings of 10, 50 and 200 watts are available for potentiometric measurements of current. All types are metal cased for oil filling. Type 3111 has water cooling tubes and a rotary impeller designed to be driven by a small motor at approx. 1000 rpm. The time constant * does not exceed $3x10^{-6}$ seconds. Types 1659 and 1682 are fitted with hand agitators. Their time constants do not exceed to 10^{-6} seconds. All these resistors are designed for use on DC and frequencies up to 1000 cps. Any resistance value between 0.0001 Ω and 10,000 Ω can be supplied on special order. Correspondence invited.

TYPE	POWER RATING IN WATTS	RESISTANCE IN OHMS	MAXIMUM CURRENT IN AMPS	% MAX. ERROR AT RATED CURRENT
1659	10	10,000	0.03	±0.03
		5,000	0.04	
		1,000	0.10	
		200	0.22	
		100	0.30	
		10	1.0	
		5	1.4	
		2	2.2	
		1	3.0	
		0.5	4.5	
		0.2	7.0	

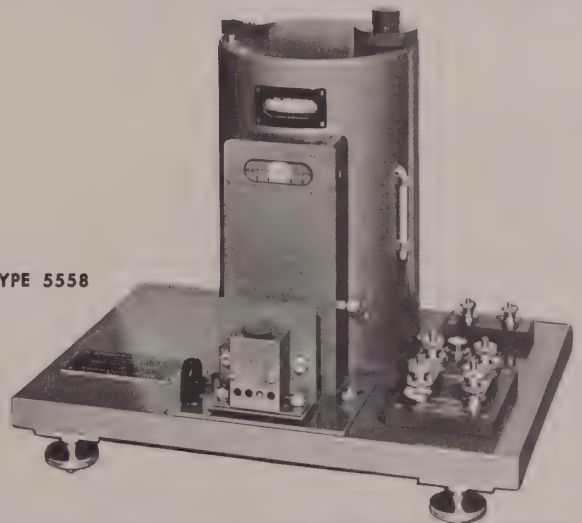
TYPE	POWER RATING IN WATTS	RESISTANCE IN OHMS	MAXIMUM CURRENT IN AMPS	% MAX. ERROR AT RATED CURRENT
1682	50	0.2	15	±0.03
		0.1	22	
		0.05	30	
		0.02	50	
3111	200	0.02	100	±0.03
		0.01	140	±0.05
		0.005	200	±0.05

DRYSDALE WATTMETER TYPE 5558

The Type 5558 is an AC/DC single phase standard wattmeter constructed to a design by Dr. C. V. Drysdale of the National Physical Laboratory in London, England. Accuracy is guaranteed to be within *.1% of full scale* up to 2000 cps. In no case does the linearity error exceed *.2% of reading* below full scale deflection down to 1/5 full scale and *every* instrument is supplied with a correction curve. It is suitable for use at power factors down to zero. NBS testing can be accomplished up to 2 kc from unity to 50% PF (lower PF's at lower frequencies). An astatic, suspension type coil system is used to reduce the effects of external magnetic fields to a minimum. Readout is on a 500 division scale. As much as possible all parts are fabricated from non-metallic materials to limit eddy currents.

The wattmeter is of the torsion head dynamometer type. Readings are taken by rotating the torsion head scale through an index line until a balance is achieved on a light spot. The torque produced by the torsion head is equal and opposite at balance to the force exerted by the deflection of the moving coil. Potential ranges are supplied in a separate multiplier. Sensitivity is 50 Ω/v.

Polyphase wattmeters also available. Prices and specifications upon request.



TYPE 5558

CURRENT RANGES	POTENTIAL RANGES	PRICE
.5/1 amp or 2.5/5 amps	50/100/200 normal 75/150/300 max.	$1618.00 F.O.B. New Rochelle, N. Y.

Special potential and current ranges available.

GALVANOMETERS

PHOTOCELL GALVANOMETER AMPLIFIER TYPE 5214

The Type 5214 Photocell Amplifier when used in conjunction with the Type SR21 Secondary Galvanometer is ideally suited for operation with DC bridges or highly accurate and sensitive potentiometers such as the Types 9144, 4363D, 9120, 9174 and 9180.

The primary galvanometer in the amplifier has a 10 ohm system and is liquid filled to reduce the effects of mechanical vibration. The galvanometer light beam differentially illuminates two barrier layer photocells which are connected in series opposition. (See Fig. 1) The photocell current resulting from an out of balance condition is used to deflect the rugged secondary galvanometer Type SR21 and at the same time to provide negative feedback. This output can also be used to feed any other resistive load of approximately 100 to 1000 ohms.

The degree of negative feedback is adjustable by means of a continuously variable potentiometer which functions as a gain control.

To avoid instability or zero drift, precautions have been taken to eliminate temperature gradients across junctions of dissimilar metals. A high insulation resistance is maintained and the copper input and output terminals are shielded from air currents by a removable cover to reduce the generation of thermal emfs.

Power to the galvanometer amplifier lamp must be supplied from an external 6 volt, 15 watt constant voltage transformer or a 6 volt lead-acid battery. Suitable transformers can be supplied for use with the amplifier. Case is of aluminum. Size is 6" x 6½" x 14" long. Weight is approx. 12 lbs.

As an optional accessory a Type 5214A Thermal Compensator is available. The Thermal Compensating unit is connected in series with the input to the Photocell Amplifier. It incorporates a four position sensitivity control and a continuously variable dial which introduces ±2 microvolts into the amplifier input circuit. This can be used to counteract thermal emfs in the wiring and make the electrical and mechanical zero of the secondary galvanometer coincident.

TYPE SR21

SECONDARY GALVANOMETER TYPE SR21

The Type SR21 Secondary Galvanometer has a current sensitivity of 0.002 μa/mm, a system resistance of approximately 500 ohms and a period of approximately 2.5 sec.

It contains on its front panel an On-Off switch, a zero adjuster, and a sensitivity switch with 4 positions giving deflection multiplying factors of 1/.1/.01/.001. Scale length is 24 cms. The scale face is marked 120-0-120 mm. It is curved on a radius of approximately the same length as the secondary light beam (about 35 cms).

The overall sensitivity of the combined amplifier and secondary galvanometer system, when connected for series feedback, is normally not less than 350,000 mm/μa at maximum gain, and when connected for parallel feedback is normally not less than 13,000 mm/μa. Series values can be increased 2 to 3 times by increasing the power supplied to the lamp to 36 w. Case is of formica. Size of secondary galvanometer is 13⅜" wide x 10⅝" front to rear x 7 3/16" high. Weight is 8 lbs. (See Fig. 2)

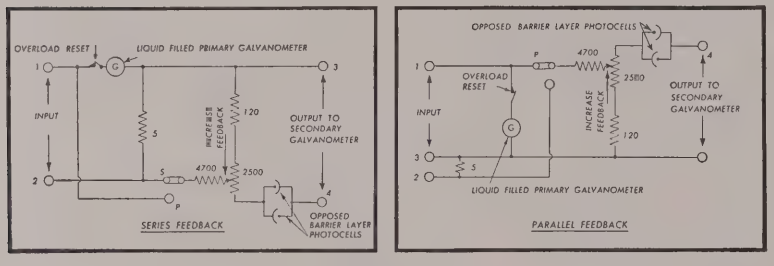


FIGURE 1.

TYPE 5214

With cover

Cover removed

TYPE 5214 Photocell Amplifier $805.00
TYPE 5214A Thermal Compensator 116.00
TYPE SR21 Secondary Galvanometer ... 283.00
TYPE 9411 (See page 11-12.)

TYPICAL SENSITIVITY AND INPUT RESISTANCE WITH 6V 15 WATT LAMP

Feedback	Gain	Input Resistance (ohms)	Current Sensitivity		Voltage Sensitivity with external circuit resistance of: Zero ohms		100 ohms		1000 ohms	
			mm/μA	μA/mm	mm/μV	μV/mm	mm/μV	μV/mm	mm/μV	μV/mm
Parallel										
Min.	Max.	0.25	13,000	0.077×10^{-3}	52×10^{3}	0.019×10^{-3}	130	7.7×10^{-3}	13	0.077
Mid.	Mid.	0.042	2,200	0.45×10^{-3}	52×10^{3}	0.019×10^{-3}	22	45×10^{-3}	2.2	0.45
Max.	Min.	0.019	1,000	1×10^{-3}	52×10^{3}	0.019×10^{-3}	10	100×10^{-3}	1	1 .
Series										
Min.	Max.	200	350,000	2.86×10^{-6}	1750	0.57×10^{-3}	1160	0.86×10^{-3}	290	3.45×10^{-3}
Mid.	Mid.	1700	350,000	2.86×10^{-6}	206	4.8×10^{-3}	194	5.15×10^{-3}	130	7.7×10^{-3}
Max.	Min.	2600	350,000	2.86×10^{-6}	135	7.4×10^{-3}	130	7.7×10^{-3}	98	10.2×10^{-3}

The above figures are typical but a variation of ±20% in sensitivity can be expected between different amplifiers due to variation in the characteristics of the photocells. If the lamp power is increased to 36 watts the current sensitivity on series feedback can be increased by two or three times but the sensitivity on parallel feedback is not substantially affected.

FIGURE 2.

GALVANOMETERS

GALVANOMETER TYPE 4500/SR4

TYPE 4500/SR4
Price $277.00

The Type 4500/SR4 is a general purpose, high sensitivity Galvanometer for use with potentiometers and in other such applications as may require a vibration free, low thermal precision null-detector.

The galvanometer has an effective optical lever arm of 150 cms, although the distance between the suspension and the scale is only 33 cms. An optical magnifier with a spherical mirror permits a sensitivity of 10X that which normally could be obtained with a suspension as rugged as the one used. Because there is only one mirror reflection external to the suspension, the sensitivity is acquired without blurring the clearly defined vertical index line in the center of the main light spot – which would not be the case if multiple mirror reflections were employed. In addition to a bright primary light spot ⅝" in diameter, the galvanometer contains a small double secondary spot with 1/10 the basic deflection sensitivity. The secondary spot is visible on the scale at all times and therefore the polarity of an over deflection can always be noted. The suspension strip passes through a drop of high viscosity, low vapour pressure oil which effectively damps the galvanometer and makes it relatively independent of bench vibrations. Thermal emfs are minimized by using copper for the external terminals and in the circuit to the suspension. Construction is generally made with high insulation resistance materials designed to provide long surface leakage paths. Scale length is 5-0-5 cms. Deflection linearity is 1% or better.

Two rotary controls are furnished on the front of the case; one is an On/Off switch and the other is a zero adjuster by which the main light spot can be moved completely over the scale. A 110/6 V transformer is self-contained to supply the galvanometer lamp. The lamp can be changed from the rear without opening the box. The galvanometer is mounted in a durable formica case with dimensions of 6½" wide x 8¾" front to rear x 7" deep. Weight is 6 lbs.

The Type 4500/SR4 is available with variations in coil resistance and additional specifications as listed to the right. Periodic time is normally 2 sec. This can be adjusted to 1 sec., but sensitivity decreases by a factor of 4.

Coil Resistance	Current Sensitivity	CDRX* (ohms)	Voltage Sensitivity with total external circuit resistance of				
				Zero ohms	100 ohms	500 ohms	1000 ohms
3	45mm/μA 0.022μA/mm	20	mm/μV μV/mm	15 0.066	0.437 2.3	0.09 11	0.043 22
5	142mm/μA 0.007μA/mm	90	mm/μV μV/mm	28.4 0.035	1.35 0.74	0.28 3.5	0.14 7.15
10	210mm/μA 0.004 7μA/mm	250	mm/μV μV/mm	21 0.047	1.9 0.52	0.413 2.4	0.21 4.8
50	450mm/μA 0.002 2μA/mm	1200	mm/μV μV/mm	9 0.11	3 0.33	0.82 1.2	0.43 2.3
140	825mm/μA 0.001 2μA/mm	3500	mm/μV μV/mm	5.9 0.17	3.4 0.29	1.3 0.77	0.72 1.4
550	225 0mm/μA 0.000 45μA/mm	12,000	mm/μV μV/mm	4.1 0.24	3.46 0.29	2.14 0.46	1.45 0.69

*External critical damping resistance

GALVANOMETER TYPE 5180

The Type 5180 liquid filled Galvanometer is unaffected by external mechanical vibration and sudden shocks which tend to break the suspensions of standard detectors. The coil is "floated" and physically damped in a liquid which is held in a sealed container. The liquid cannot move or run out, and therefore does not transmit any movement to the coil. Resistance of the coil is either 10, 50, 140 or 450 ohms for a respective sensitivity at 1 meter of either 80, 170, 330 or 875 mm/μa. The galvanometer is normally supplied unmounted, without a scale or optical system, for inclusion in OEM or other specialized test equipment. It can be packaged to specifications on special order.

TYPE 5180 Price $275.00

Correspondence is invited concerning the availability of special galvanometers for individualized applications.

CHOPPERS

LOW THERMAL CHOPPERS TYPES 9742, 9743, and 9744

The Types 9742, 9743, and 9744 are motor driven Low Thermal Choppers that have resulted from design work accomplished at the National Research Council in Ottawa, Canada. The construction of the choppers makes them particularly adaptable to circuits where thermal noise is of importance, such as in low level DC amplifier applications and Hall Effect measurements.

SPECIFICATIONS

THERMAL EMFs: 0.02μv or less.

CONSTRUCTION: Depending on Type No. contain 2, 3, or 4 DPDT switches, all actuated by a common shaft. Switch arms are made of copper. Contacts are solid gold blocks. Switch sections are separated by electrostatic screens and surrounded by heavy metal covers to maintain thermal equilibrium.

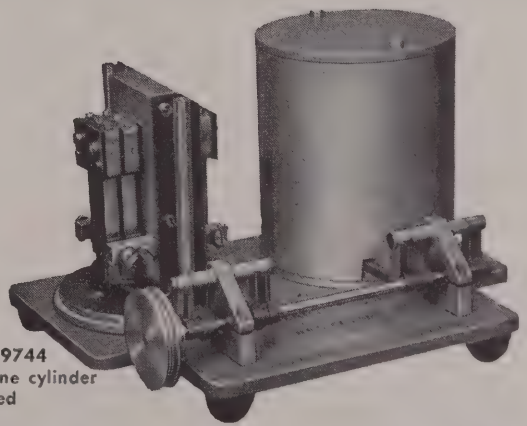
RELATIVE PHASE OF SWITCHES: Adjustable through 360° by rotating the cams on the shaft.

MAKE/BREAK RATIO: Each contact can be separately adjusted from 0 to 100% of a cycle with an accuracy of ± 1%.

CURRENT CAPACITY: Depends whether circuit is resistive, capacitive or inductive. Will usually operate in purely resistive circuits to interrupt up to 100 millivolt amperes. Correspondence necessary for special applications.

CHOPPING FREQUENCIES: Speeds up to 60 cps. are normal. Optimum speed depends on applications, i.e. in a DC amplifier operating from a 60 cycle supply, a maximum rejection of 60 cycle pick-up can be obtained at a speed of approximately 37.5 cps. Speeds up to 90 cps. can be used by increasing the tension of the spring on the rod return.

DRIVING MECHANISM: A small synchronous motor capable of a 0.8 inch-oz. torque. (Not furnished)



TYPE 9744
with one cylinder removed

TYPE	SIZE	WEIGHT	PRICE
9742 (2 switches)	3¾" x 5½" x 4½" high	4 lbs.	$295.00
*9743 (3 switches)	3½" x 5¼" x 4" high	2 lbs.	381.00
9744 (4 switches)	7½" x 5½" x 4½" high	9 lbs.	500.00

*Type 9743 miniaturized for OEM applications.

SWITCHES

LOW THERMAL SELECTOR SWITCH TYPE 9145

TYPE 9145
Price $343.00

The Type 9145 Low Thermal Selector Switch is intended for use in potentiometer or other circuits where stray emfs must be kept to an absolute minimum. *Maximum generation of thermal emfs is less than 0.01* μv. The switch contains 4 DPST sections with self-wiping gold-silver alloy contacts and is mounted in a solid block of aluminum to minimize temperature gradients. Operation is made simple by allowing for the selection of any one of 4 circuits by merely depressing a push button. The buttons lock down automatically and release when any other button is depressed. Two or more buttons may be simultaneously depressed if desired. A separate release button is provided to open all circuits. The terminals can be cross connected for applications requiring a reversing switch. Size is 5⅞" x 2⅞" x 3⅛" high. Weight is 2.5 lbs.

The Type 9145 is ideally suited for use as an external circuit selector with the Type 9144 Dauphinee Potentiometer.

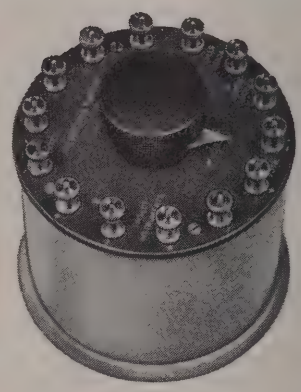
REVERSING SWITCH TYPE 9600

The Type 9600 is a Reversing Switch designed to simplify and speed up the operation of precision potentiometers. By a single turn of the switch the potentiometer battery and two measuring circuits are reversed and the galvanometer is disconnected during the change over. If only one measuring circuit is in use the spare section of the switch can be utilized to reverse the standard cell and thus make it possible to check the standardization of the potentiometer with either a positive or negative connection of the battery.

To eliminate errors due to thermal emfs in potentiometric measurements the balance point must be adjusted until the galvanometer deflection does not change on reversal. To perform this function effectively, the reversing switch has two outstanding characteristics: 1) In the measuring circuits and the galvanometer circuit the switch does not generate significant thermal emfs. It has copper switch contacts and low thermal solder at all junction points. The complete switch and internal wiring are immersed in oil; 2) In the battery circuit the switch contacts do not introduce a change in resistance large enough to significantly affect the potentiometer current. The design of the switch allows for an extremely high reproducibility of contact resistance. The maximum change of resistance on reversal does not exceed 100 $\mu\Omega$. In a typical potentiometer of 100 Ω resistance this would cause a change in current of 1 ppm.

The switch is enclosed in a cylindrical metal case with rubber feet. Overall size is 5½" dia. x 6" high. Weight is 6 lbs.

The Type 9600 is recommended for use with all COMMANDER potentiometers except the Dauphinee Type 9144.



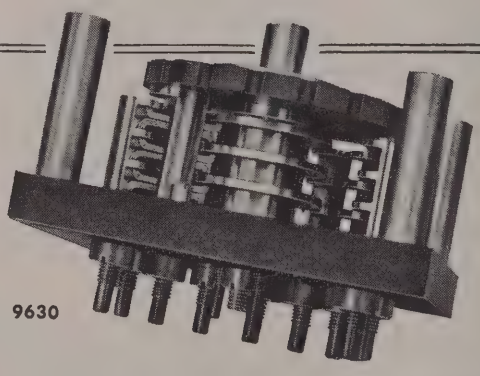
TYPE 9600
Price $440.00

DUAL CONTACT SWITCHES TYPE 9630

A wide variety of standard and special Dual Contact Switches are available for AC/DC transfer and/or reversing applications demanding the highest degree of precision and reliability. The principle of the dual contact switch is illustrated in the accompanying photograph.

The complete wiper or brush is made up of two assemblies, each with 8 individually sprung contact arms that are separated and riveted together at the center. The elasticity of the wiper arms maintains the whole assembly against the inner surfaces of the center segments of the brush and the stationary contacts. This arrangement effectively allows the wiper to "float" between the stationary contacts since it is not mechanically held in place other than by the pressure of its own individually sprung arms. Hence, contact pressure — and therefore, contact resistance is always constant. Contact surfaces are self-cleaning and the design of the wiper assembly is patented with all rights reserved.

The switch contacts are constructed of tellurium copper. The generation of thermal emfs can be kept as low as .01 μv. For exceptionally low resistance applications, the wiper assemblies can be paralleled. Resistance is as low as 100 $\mu\Omega$ between soldering points and varies less than 10 microhms between contact points.



TYPE 9630

Standard switches with either 5/16" or ½" diameter contacts are available in varying combinations of 1 — 4 poles and 2 — 25 positions. (A maximum of 4 positions for a 4 pole single deck switch.) As many as 6 decks can be supplied actuated by a single shaft. Correspondence is invited on both standard and special switches.

Type 9630 Prices	Poles	5/16" Stud Diam.			3/8" Stud Diam.			1/2" Stud Diam.		
		Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.	Base Price 2 Pos.	Add. Price Per Pos.	Max. Poss. Pos.
SINGLE BRUSH	1	$ 63	$ 1	25	$ 67	$ 1.50	25	$ 73	$ 2	16
	2	81	2.50	12	83	4	12	85	6	6
	3	95	10	7	98	14	6	104	8	3
	4	106	15	4	126	17	4	147	—	—
DOUBLE BRUSH	1				$ 77	$ 2	25	$ 80	$ 3	16
	2				95	5	12	97	9	6
	3				113	16	6	116	16	3
	4				146	21	4	168	—	—
TRIPLE BRUSH	1							$256	$ 7	11

POTENTIOMETERS

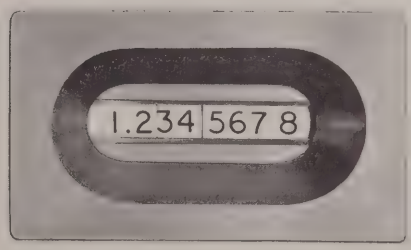
COMMANDER potentiometers are designed to be "Self Checked" by the user. The method and technique described in the instruments' operating instructions are the same as adopted by national standardizing laboratories as the most accurate way of certifying a ratio device. In most potentiometers, "Self Checking" is difficult to accomplish, but all COMMANDER instruments incorporate the necessary switching and additional taps to make this a relatively simple procedure. The only accessory equipment needed is a galvanometer of proper sensitivity and a stable potential divider, or another potentiometer, whose absolute accuracy is unimportant. "Self Checking" as a method of certifying has a distinct advantage over checking by comparing against other instruments in that it eliminates the error or uncertainty of another standard.

Particular attention is paid in construction to the elimination of thermal emfs. All potentiometer terminals are made of tellurium copper. The 4 galvanometer sensitivity keys, Low (L), Medium (M), High (H+) and reverse galvanometer (H−) generate less than 0.01 μv thermal emfs even though they are self-wiping. (This switch is available separately as the COMMANDER Type 9145.) Close thermal bonding is observed in the construction and assembly of all dials and switches. All potentiometers are provided with excellent thermal and electrostatic shielding and thermal insulation.

7 FIGURE DC POTENTIOMETER TYPE 9120

TYPE 9120

SINGLE WINDOW READOUT



The Type 9120 is a 4 dial, 7 figure precision DC potentiometer with *single window readout and resolution of 1 part in 20 million.* Total measuring span of 2.099,999,9 volts is achieved *without a change of range.* The potentiometer is designed for use as a general purpose high accuracy measuring instrument with special emphasis on simplicity of operation and readability. It has particular value when voltages requiring usage of the first dial are to be compared to a fraction of a microvolt as in the measurement of the emf of standard cells or in the potentiometer comparison of resistors.

The Type 9120 consists of two potentiometers in tandem, with special provision for a simplified method of standardization. The upper potentiometer battery current is controlled by a 5 dial rheostat. Dials 1 and 2 give 20 steps of 0.1 volt and 99 steps of 0.001 volt. The lower potentiometer is supplied from a dry cell with zener diode control. This design eliminates frequent restandardization of the lower potentiometer.

The low, medium and high sensitivity standardizing switch connects the galvanometer to the standardizing circuit which incorporates 9 resistors of dial 1 and the total of dial 2, and which can be adjusted to better than 1 μv. The same standardizing switch is used to compare the total of dial 3 with the first step of dial 2 and small corrections of the lower potentiometer current are easily made if necessary. The lower potentiometer gives 99 steps of 10 μv and 99 steps of 0.1 μv.

"Self Checking" facilities are built in to enable a complete calibration check by the user. All 20 steps of dial 1 can be compared with the total of dial 2. Groups of 10 steps of dials 2 and 3 can be compared with built-in check resistors. When checking dial 3, the current in the lower potentiometer can be increased by 10 times to improve sensitivity.

Special attention is called to the convenience of operating only 4 switch dials to read 7 significant figures. *An outstanding feature is that none of the measuring circuit dials carries current. Switch contact resistance is, therefore, of no importance.* Each switch position is an individually calibrated step and a slide wire with its attendant difficulties is not employed.

ADDITIONAL SPECIFICATIONS

Accuracy:	± (0.0015% of reading + 0.1 μv)
Total Measuring Range:	0 to 2.099,999,9 v
Resolution:	± 0.1 μv
Standard Cell Range:	1.0175 to 1.0201
Standard Cell Dial Resolution:	± 1 μv
Battery Current and Voltage:	20 ma at 6 v and 5 ma at 22.5 v
Measuring Circuit Resistance:	Dials 1 and 2, 50 ohms/v
Recommended Galvanometer:	COMMANDER Types 5214 Galvanometer Amplifier and SR21 Secondary Galvanometer
Case:	Formica; 28" x 14½" x 6½" deep
Price:	$4115.00

POTENTIOMETERS

5 FIGURE DAUPHINEE DC POTENTIOMETER

TYPE 9180

The Type 9180 is a 3 dial, 5 figure precision DC vernier potentiometer. Its design is a simplified version of the Type 9144 potentiometer circuit designed by Dr. T. M. Dauphinee of Canada's National Research Council.

This excellent general purpose low thermal potentiometer is capable of high accuracy measurements at both high and low voltage levels. An optional −0.01 to +2101.00 μv range is available with additional errors from all extraneous signals generated in the instrument limited to 0.05 μv or less. Since the accuracy of a potentiometer is expressed in terms of reading plus a set figure for such signals, this is of primary importance when usage is for measurements below 1 mv. As an example, when making measurements at the 500 μv level, a potentiometer with uncertainties of 5 μv due to zero errors and thermal emf's has a possible uncertainty of 1% plus the error of its fundamental accuracy guarantee. Employing the Type 9180 in such an application provides the user with an accuracy of .012% at the very least *or this potentiometer has nearly 100 X more accuracy when measuring or comparing below 1 mv.*

When employing the Type 9180 at higher voltage levels, its accuracy is essentially 20 ppm of reading. Stability is guaranteed to 2 ppm/year for a period of 5 years. Resolution to 5 places can be increased to a precision 6th figure by using the Type 5214 Photocell Amplifier and SR21 Galvanometer and interpolating on the galvanometer scale.

Special attention is called to the convenience of operating only 3 switch dials to read 5 significant figures. Each switch position is an individually calibrated step and a slide wire with its attendant long term difficulties is not employed.

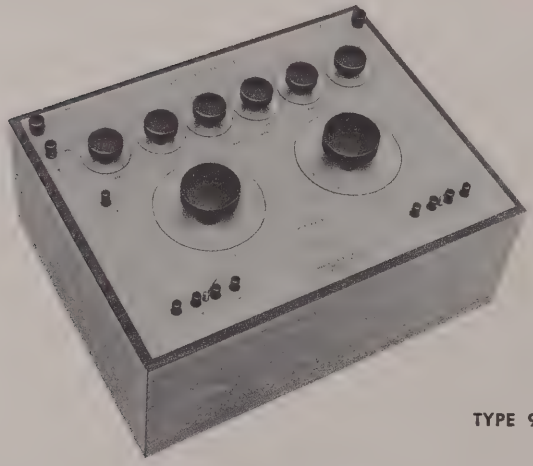
TYPE 9180

ADDITIONAL SPECIFICATIONS

RANGE FACTOR	MEASURING RANGE	RESOLUTION	ACCURACY
x1	−10 μv to 2.10100 v	10 μv	± (0.002% of reading + 1 μv)
x0.1	−1 μv to 0.210100 v	1 μv	± (0.002% of reading + 0.5 μv)
x0.01	−0.1 μv to 0.0210100 v	0.1 μv	± (0.002% of reading + 0.1 μv)
OPTIONAL RANGE			
x0.001	−0.01 μv to 0.00210100 v	0.01 μv	± (0.002% of reading + 0.05 μv)

Standard Cell Range:	1.0175 to 1.020 v
Standard Cell Dial Resolution:	1 μv
Battery Voltage and Current:	6 v and 20 ma
Measuring Circuit Resistance:	50 ohms/v
Shielded:	Yes
Recommended Galvanometer:	COMMANDER Types 5214 Galvanometer Amplifier and SR21 Secondary Galvanometer or Type SR4 Galvanometer with 10 ohm internal resistance
Case:	22″ x 12½″ x 9″ high; formica with dust cover
Price:	A. $2,366.00 (3 range) B. $2,554.00 (4 range, includes optional x0.001 range)

4 FIGURE DC MICROVOLT POTENTIOMETER TYPE 9174



TYPE 9174

ADDITIONAL SPECIFICATIONS

RANGE FACTOR	MEASURING RANGE	RESOLUTION	ACCURACY
X1	−0.1 μv to 1010 μv	0.1 μv	± (0.01% of reading + .05 μv)
X0.1	−0.01 μv to 101 μv	0.01 μv	± (0.01% of reading + .02 μv)

Standard Cell Range:	1.018 to 1.019 v
Standard Cell Dial Resolution:	10 steps of 100 μv
Battery Voltage and Current:	2 v and 5 ma
Measuring Circuit Resistance:	0.2 ohm/step on Dial 1
Recommended Galvanometer:	COMMANDER Types 5214 Galvanometer Amplifier and SR21 Secondary Galvanometer
Case:	18″ x 14″ x 9″ deep; formica
Price:	$2023.00

The Type 9174 is a 2 dial, 4 figure, low range DC potentiometer for precision measurements in the area of −.1 to 1000 μv. Its particular value is in applications where *high accuracy, low level voltage comparisons are mandatory.* It supplements potentiometers with total measuring ranges of 1.6 to 2 v, since it is often more accurate at lower levels even though its fundamental precision is equal or less.

The accuracy of a potentiometer is expressed in terms of reading plus a set figure for extraneous signals such as zero error and thermal emf's. A high range potentiometer has a greater fixed error from these sources than an instrument designed for use at lower voltages only. It is easy to see, therefore, that a potentiometer with better than normal accuracy of ± (0.005% of reading + 5 μv) has a possible uncertainty of more than ± 5% when measuring at the 100 μv level. Conversely, the Type 9174 having an accuracy of ± (0.01% of reading + .02 μv), when used for the same measurement, has a possible uncertainty of only ± 0.03% – or in this application it is almost 200 X more accurate than the high range potentiometer that has twice the fundamental precision.

"Self Checking" facilities are built in to enable a complete calibration check by the user. To improve sensitivity during the checking procedure, the voltage across the potentiometer can be increased from 0.001 to 1 v.

Special attention is called to the convenience of operating only 2 switch dials to read 4 significant figures. Each switch position is an individually calibrated step and a slide wire with its attendant difficulties is not employed.

Extraordinary care has been paid in construction to the elimination of thermal emf's. All terminals are made of tellurium copper and are covered by a removable panel which can remain in place during operation to guard against undesirable effects from air currents.

PORTABLE STANDARD CELL ENCLOSURE

PORTABLE SATURATED STANDARD CELL ENCLOSURE TYPE 9152P

The Type 9152P is a portable constant temperature air bath designed to reduce the hazards involved in transporting saturated standard cells. It is an ideal transfer standard when direct intercomparison of saturated standard cells is desired between a calibration laboratory and NBS or between variously located calibration facilities of the same organization.

The enclosure accommodates three saturated cadmium cells constructed with a porous partition to greatly improve portability. The standard cells can be certified to ± .0001%. Weight (30 lbs.) and box size (18″ L x 10″ W x 10″ H) are convenient for hand carrying. Provision is made for operation from a portable battery pack, a 110 volt AC line or a car cigarette lighter outlet.

The enclosure is maintained at a nominal 32°C and is guaranteed not to vary more than ± .01°C even after continuous exposure to ambient temperature down to 0°F (−17.8°C) in still air. (In actual test, prototype units were monitored for two weeks in such an ambient temperature and showed maximum internal variations of 0.002 to 0.003°C, which is nearly normal for operation in a closely controlled laboratory.

The Type 9152P is similar in concept to the standard Type 9152 (on page 11-4) except for its exceptional insulation, and modifications made in size, weight and number of cells. It can best be described as "an enclosure within an enclosure." Temperature changes are detected by a thermostat which operates a transistor switch and controls the current in the heaters. A self-contained thermistor bridge serves as an internal temperature sensing element. If the bridge is connected to a 1.5 volt dry cell and a galvanometer, temperature stability can be checked to within ± 0.001°C. A calibrated dial with 12 divisions, having a value of 0.01°C per division can be continuously adjusted to null the galvanometer. The position of the dial indicates the variation of the internal temperature from nominal.

Note that the enclosure does not utilize a thermometer to read out internal temperature. *The thermistor bridge detects and indicates variations from a set nominal temperature only.* Since the saturated standard cells are certified in the enclosure, the important consideration is this variation, not the absolute temperature maintained inside. This concept eliminates one possible source of error in certification since

TYPE 9152P (includes 3 cells)
PRICE $1138.00

cells that are removed from their normal bath for checking in another enclosure could have some inaccuracies because of the difficulty in matching or measuring *exactly* the temperatures of two different baths in different locations, using different temperature measuring standards. The Type 9152P enclosure is also superior because (1) it does not have insertion holes to the outside which materially reduce thermal lagging, and (2) it eliminates the chance of damaging cells from excessive handling.

The thermistor bridge, "on" "off" lights and binding posts are located on the front end as pictured. A protective cover for this panel is furnished for use while the enclosure is in transit. The standard cell binding posts are mounted on the top of the case and are covered by a bakelite panel. The external paneling of the box is made of tough, durable formica.

When connected to a 110 v/60 cps supply, the portable battery pack (or a lead acid battery) can be connected for automatic 12 volt DC operation upon failure of the AC supply. An automatic overload protection system shuts off power to the enclosure if its thermostatted temperature is exceeded by 3°C. The portable battery pack is available as optional equipment. It contains 8 rechargeable batteries in a leather carrying case with all connections and leads for use with the Type 9152P. Price upon application.

AMPLIFIER

DC AMPLIFIER TYPE 9790

The Type 9790 high sensitivity DC amplifier is designed for the detection and measurement of low level DC signals in the fractional microvolt range. It utilizes a COMMANDER Type 9742 low thermal chopper as a modulator-demodulator. This chopper is constructed in accordance with a design by Dr. T. M. Dauphinee of Canada's National Research Council. *It introduces less than .01 μv of extraneous signal into the output.* The amplifier is particularly suitable for the long term recording of low level voltages such as may be obtained from a thermistor bridge or thermocouple used to detect small temperature changes.

The design incorporates several features not previously available in commercial DC amplifiers, such as:

1) Immediate recovery from overloads of 10,000 times full scale
2) 0.03 μv full scale lowest range
3) 0.003 μv stability over a 24-hour period
4) Easy accessibility for maintenance purposes

TYPE 9790

ADDITIONAL SPECIFICATIONS

Output:	1 ma into 1500 ohms, or 1 mv, 10 mv or 100 mv full scale. Suitable for 1 ma recorder or potentiometric recorders.
Input Resistance:	50 ohms to 1000 ohms according to input transformer used.
Ranges:	Gain control consists of 21 switch positions and a continuously variable control. **Calibration Signals** applied in series with the input are 0.03/0.1/0.3/1/3/10/30/100/300 μv, accurate to ±5%.
Zero Suppression or thermal emf compensation:	A steady, continuously variable emf can be introduced in series with the input circuit in any one of the following four ranges ±0.3 μv, ±3 μv, ±30 μv or ±300 μv.
Response time:	From 2 to 5 seconds to 90% of full scale, depending on the output filter used.
Overload recovery:	Will recover to give no readable difference after 10,000 times overload in a maximum time of 12 seconds with the maximum filter in the circuit.
Stability:	With input short circuited and after 1 hour warm up, instability not greater than 3 milli-microvolts over a twenty-four hour period.
Case:	19″ x 12″ x 9″ deep; grey aluminum; rack mount or bench type.
Price:	$2183.00

CURRENT CONTROLLER

AUTOMATIC CURRENT CONTROLLER 9770

The Type 9770 is designed to control automatically the current supplied to a DC potentiometer or to any circuit requiring a stable current in the range of 10 ma to 100 ma. Its primary application is to eliminate the current drift which is normal with lead acid batteries. Batteries which are run down, newly charged, or have just been momentarily disconnected, are prone to drift, making potentiometer restandardization necessary at frequent intervals. This is a limitation on the value of continuous long term monitoring of a circuit, and the making of precision high accuracy measurements for data comparison purposes, since there is always the possibility, in such cases, that standardization was not accurate at the time the measurement was made. The automatic controller eliminates this problem by placing a positive control on the battery output and assuring continuous balance against the standard cell used as an external reference.

The controller is supplied from an external 12-volt battery. It contains an internal reference cell mounted in a constant temperature enclosure, so that voltage drift in the cell due to ambient temperature changes is reduced to a minimum. In operation, the load current passes through an adjustable resistor across which a voltage equal to the reference voltage is developed. This resistor may be adjusted to produce the required voltage drop for nominal current values from 1 ma to 100 ma by two continuously variable fine controls. Any difference occurring between the voltage drop due to the controlled current, and the voltage of the reference cell is detected and a continuous correction is automatically made. Current stability is, therefore, almost entirely dependent on the stability of the reference voltage. The cell is used only as a convenient reference and its exact voltage need not be known.

TYPE 9770

A newly charged lead acid battery, if connected directly to a potentiometer, could not be expected to be usable for periods of time ranging from a few hours to 2 weeks. When connected to the Automatic Current Controller, it can be employed to supply a stable current immediately, and to maintain this stability throughout the life of the battery whether the battery is on continuous or intermittent load.

ADDITIONAL SPECIFICATIONS

Current Stability:	± (1ppm + stability of the reference cell)
Output:	1 ma to 100 ma at 10 volts
Max. Load Resistance:	1000 Ω
Case:	12" x 7" x 6" high; formica
Price:	$1154.00

GALVANOMETER

GALVANOMETER TYPE 9411

TYPE 9411

The "COMMANDER" Type 9411 light spot galvanometer is a vibration free, high sensitivity null detector designed for vertical panel mounting. Its relatively low cost (compared to other galvanometers with similar performance characteristics) makes it ideally suited for inclusion in OEM applications as well as for "in plant" test equipment.

Particular attention is paid in the construction to assure a rugged instrument that is simple to mount and easy to use and maintain. So that operation and readability are not affected by normal vibration, the taut band strip that suspends the moving coil is passed through a single drop of high viscosity, low vapor pressure oil. The ¾" diameter brightly illuminated light spot has a well defined hairline for the detection of very small deflections. The optical lever arm length is 18" and deflection linearity is better than 1% over a 10 cm scale. Zero correction is made via a knob mounted on the front of the case. Adjustment can be made over the entire scale length.

The movement is provided with a transit lock to prevent damage in shipment. The light spot bulb can easily be changed from the rear of the case without dismantling the galvanometer from the panel. Mounting of the instrument is by means of four screws. A 110/6 v transformer is required but not furnished.

ADDITIONAL SPECIFICATIONS

Current Sensitivities and Coil Resistances as listed below:

RESISTANCE (Ω) COIL	CURRENT SENSITIVITY
3	4.5 mm/μa .22 μa/mm
5	14.2 mm/μa .07 μa/mm
10	26 mm/μa .047 μa/mm
50	45 mm/μa .022 μa/mm
140	82.5 mm/μa .012 μa/mm
550	225 mm/μa .0045μa/mm

Scale:	5-0-5 cms
Resolution:	1 mm/division, 100 div.
Case:	Aluminum
Size:	11¾" x 6" x 6" d
Weight:	4.5 lbs. aprox.
Shipping Weight:	9 lbs. approx.
Price:	$196.00 f.o.b. New Rochelle, N. Y.

Discounts available for quantity users. Duty-free certificates apply to quantities of 10 or more f.o.b. Rouses Point, N. Y. Correspondence invited.

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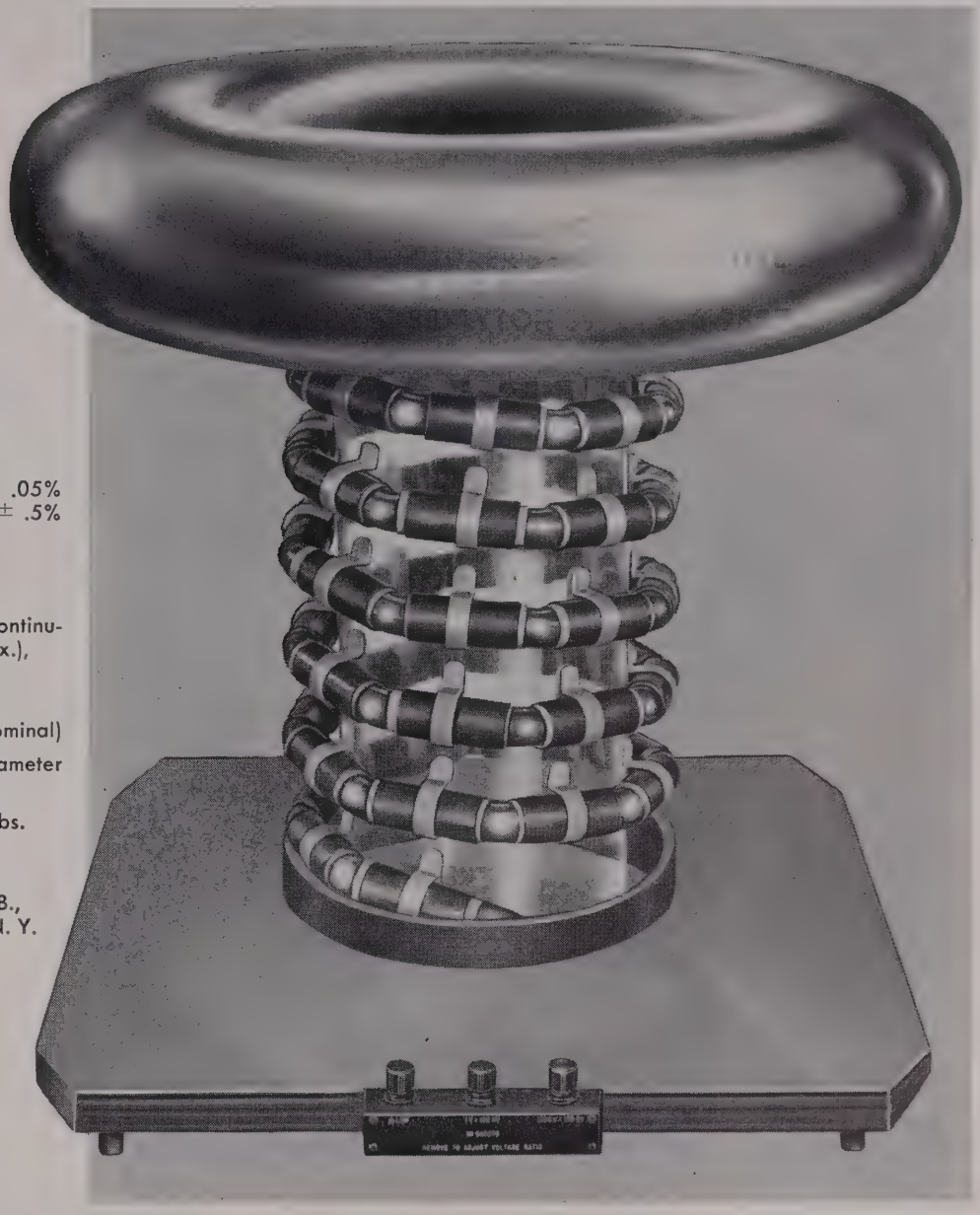
SENSITIVE RESEARCH .05% ACCURATE HIGH VOLTAGE DIVIDER

THE PARK DIVIDER



SPECIFICATIONS

RANGE:	100 kv (max.)
DC RATIO ACCURACY:	100 kv to 1 v ± .05% 100 kv to 1 kv ± .5%
AC RATIO ACCURACY:	50 kv (max.) to 500 v ± .5%
DUTY CYCLE:	50 kv (max.), continuous; 100 kv (max.), 15 min./hour
TOTAL RESISTANCE:	100 megohms (nominal)
SIZE:	22¼" h x 22" diameter
APPROX. WEIGHT:	50 lbs. net; 95 lbs. shipping
SPECIFY:	Model PARK
PRICE:	$3250.00 F.O.B., New Rochelle, N. Y.

Note: Ratio accuracy of ± .05% at 100,000 to 1 is conservatively set pending additional stability testing with time. Current data indicates stability better than ± .02% and initial adjustment within ± .01% of the National Standard.

A new voltage divider constructed to a design by J. H. Park. *(Ref.: "Journal of Research" of National Bureau of Standards, Engineering and Instrumentation Vol. 66C, No. 1, Jan.-Mar., 1962.)* Each 100 kv unit consists of 100 individually shielded one-megohm resistors, matched to each other to achieve an approximate temperature coefficient of less than 1 ppm/°C, and connected in series to form a vertical helix between a ground plate and a high voltage electrode. Uniquely shielded, testing indicates that corona, heating and leakage errors are less than 10 ppm at 50 kv and 50 ppm at 100 kv. The divider's special "hat" or high voltage electrode is designed to give uniform gradients from it to ground, and allows stacking of additional 100 kv units for higher voltage measurements. Each unit is only 22¼" high!

The Park Divider, while mainly designed for DC, can also be used for AC (60 cps only) measurements to 1% overall accuracy or better. AC accuracy is based on the use of an S.R.I.C. .5% Model ESD electrostatic voltmeter. Specifications can be supplied on high accuracy, precision DC potentiometers for readout of 1 v or less.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y.

SENSITIVE RESEARCH

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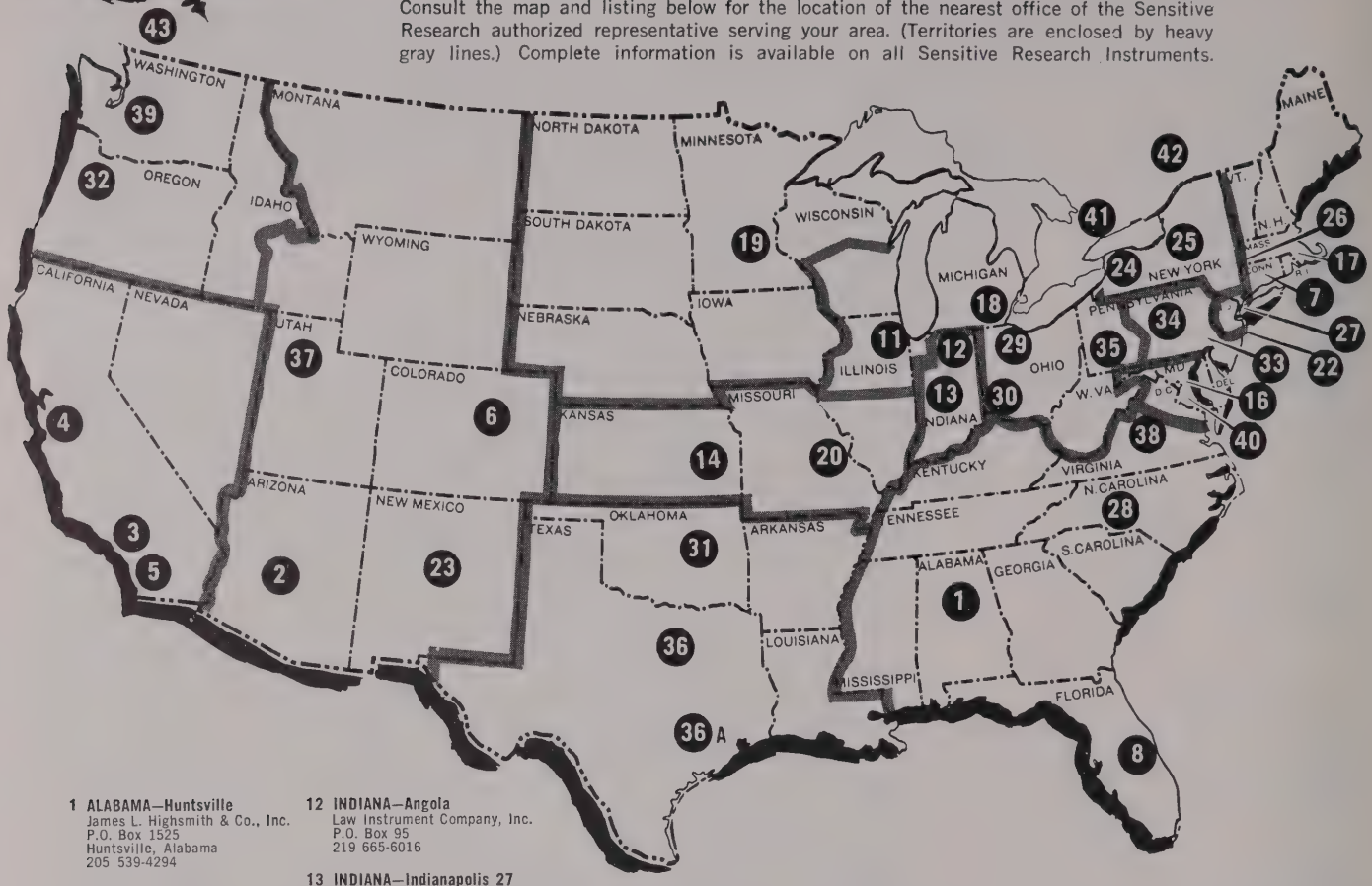
Consult the map and listing below for the location of the nearest office of the Sensitive Research authorized representative serving your area. (Territories are enclosed by heavy gray lines.) Complete information is available on all Sensitive Research Instruments.



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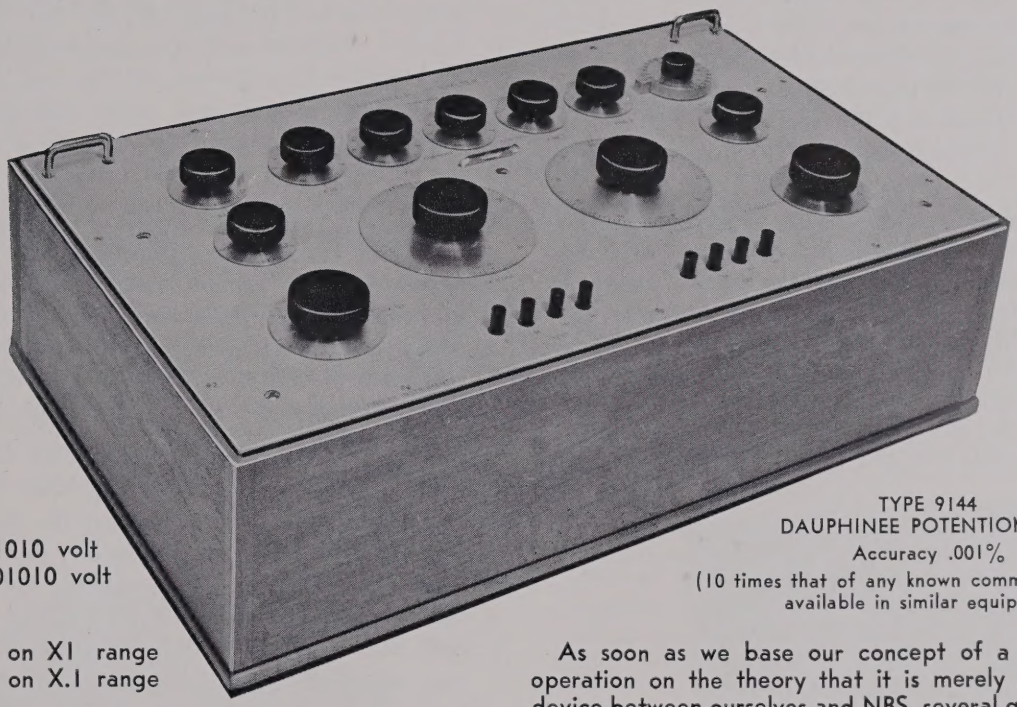
COMMANDER INSTRUMENTS

PRINTED IN U.S.A.

Electrical MEASUREMENTS

VOLUME 28 | FEBRUARY, 1961 | NUMBER 2

A SELF SUFFICIENT ELECTRICAL STANDARDS PROGRAM



Ranges
X1 to 2.101010 volt
X.1 to .2101010 volt

Resolution
1 microvolt on X1 range
.1 microvolt on X.1 range

TYPE 9144
DAUPHINEE POTENTIOMETER
Accuracy .001%
(10 times that of any known commercial accuracy available in similar equipment)

ELECTRICAL STANDARDS DEPARTMENTS come in all sizes and shapes. They may be in one corner of a bench someplace in an out of the way section of the plant. They may occupy floors of carefully air-conditioned, humidified rooms, with much equipment and many people or, they may be somewhere between these two extremes. However, fundamentally, they all exist for exactly one purpose — that is to show the relationship between electrical measurements made in the plant and those made at the National Bureau of Standards in Washington, D. C. or Boulder, Colorado.

Absolute measurements represent many man months for a single determination of current or resistance and, hence, are impractical for any except such national standardizing institutions as NBS.

As soon as we base our concept of a standardizing operation on the theory that it is merely a comparison device between ourselves and NBS, several questions arise. First, does our standards department become merely a repository of a group of duplicate measuring equipment similar to that used in the plant, with this equipment continually shuttling back and forth between ourselves and the Bureau? Or, do we set up only one or two fundamental standards from the Bureau and derive the balance of our measurements from these standards and, if we do this, what are the units which we use for NBS transfer?

There are many versions of the answers to these questions. If we operate on the first proposed scheme of "keep a duplicate of everything and send it to the Bureau," we soon find ourselves in trouble. Many of the pieces of gear which we would like to use in this fashion do not have sufficient long-term stability to justify such travelling to and from the Bureau.

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Also, if enough people adopt this sort of philosophy, the Bureau of Standards would soon be so overloaded that it would be impossible for them to keep up with the tremendous number of routine measurements.

In many fields the NBS is already reaching this situation and, of necessity, they must then cut back on the routine measurements, in order to conserve their personnel for the more important and technically rewarding fields of working on tomorrow's measurements rather than today's routine calibrations.

Suppose we take the opposite approach and ask ourselves the following question: "What is the absolute minimum of cross checking equipment we require in order to maintain satisfactory wide range standards in our own plant for long periods of time." This question starts us looking at the overall long-term stability of the various electrical standards.

We find first, that saturated standard cells maintained at a constant temperature, provide an excellent long-term stability device for the maintaining of standard voltages. The working standard of voltage for the United States is maintained by the National Bureau of Standards in the form of about 30 saturated standard cells, most of which are about 40 years old.

The assured drift rate of such a bank of saturated cells is such that yearly cross-checks by means of a portable standard with the Bureau of Standards in Washington or Boulder, would be ample to assure accuracies in the order of four or five parts per million. A look at unsaturated cells, however, shows that the great majority of these units have a steady drift which, unfortunately, may be either up or down and, hence, are not satisfactory for maintaining long-term stability although they are commonly used for interim measurements, plant standards, secondary working standards and things of this general class.

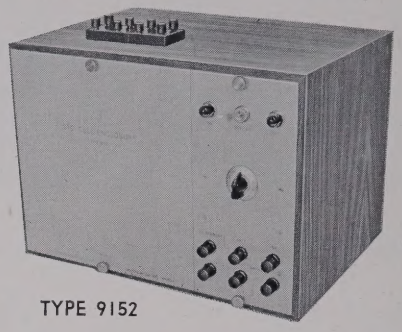
MODEL STV
Accuracy .01%

All types of standard cells are subject to damage from overload if they are abused when current is drawn from them in any appreciable amount. For this reason, many standards groups are changing to the Sensitive Research Model STV, standard voltage source, for secondary voltage standards instead of using unsaturated standard cells. The stability is comparable with such unsaturated cells and the fact is that they are so immune to abuse, standing a short circuit indefinitely without damage, that they provide a more satisfactory reference. They will, of course, for utmost accuracy, require a regular check against a saturated bank for purposes of certification.

The inescapable conclusion then is that the Standards Department will require a bank of saturated standard cells in a constant temperature enclosure. The **COMMANDER*, type 9152, is an excellent example of such a device.

Having established our own voltage standard, we require either a current standard or a resistance standard in order to be able to accomplish all our measurements. Current is ob-

Accommodates Four Standard Cells



Temperature variations held within ± .01 C°

TYPE 9152

viously a transient phenomenon and, hence, it is physically impossible to establish a current standard as such. However, when we look at resistance, we find that the four terminal NBS types of resistance as designed originally by Dr. Thomas of NBS, show excellent long-term stability and relative immunity to reasonable overloads and, hence, provide a very satisfactory basic standard. We find that yearly checks of such resistors are satisfactory to maintain accuracies in the general order of four or five parts per million.

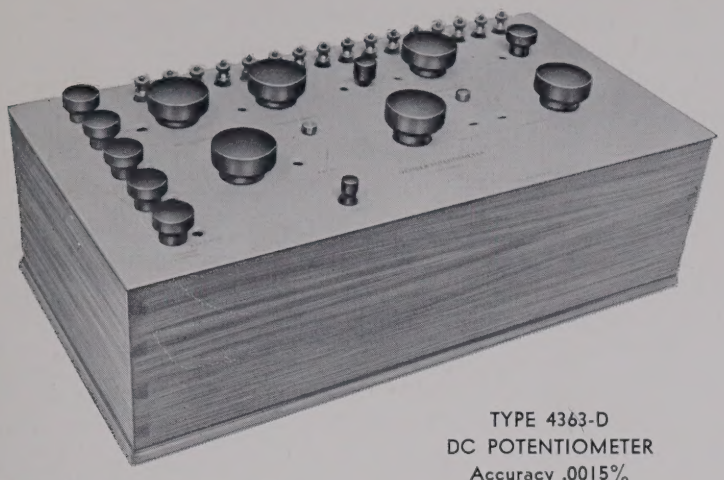
These four or five parts per million will probably not be obtained, or at least be completely assured, until one has a working history on the standard cells and resistances. In general, it is suggested that these instruments be certified by the Bureau of Standards at the time they go into service and at the end of six months, and then probably yearly thereafter will be ample to maintain this working accuracy.

Having established satisfactory basic standards for voltage and resistance and by combining the two, also standards of current, we find we need satisfactory devices for extending the ranges of operation. We need, for instance, to be able to measure voltages other than that of our standard cell bank, both higher and lower. Lower, of course, means a high accuracy potentiometer, which will cover the range from the general vicinity of standard cells, or a little above, on down through into the millivolt and, in some cases, microvolt range.

If we are to attempt to maintain comparisons, sufficiently valid to be reasonable for use with the standards just established, we require a potentiometric linearity at least comparable with the absolute values of resistance and voltage which we have set up. This means we need resolution of at least one part per million and we need absolute accuracy in terms of potentiometer linearity of possibly somewhat less than this.

Such equipment is represented by the *COMMANDER* 9144, the *COMMANDER* 4363-D and the *COMMANDER* 3589-S potentiometers. All of these units have accuracies in this range and are satisfactory for measurements from a few microvolts up to one or two volts (except in the case of the 3589-S which has a top voltage of .11111 volts) with resolution and basic linearity sufficient for use with these standards.

*All "COMMANDER" instruments are manufactured for "Sensitive Research" by Guildline Instruments, Limited, Canada.



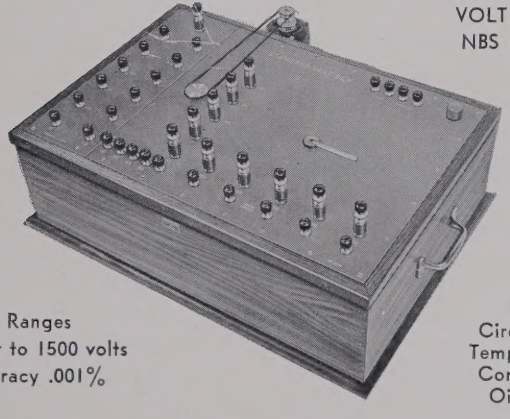
TYPE 4363-D
DC POTENTIOMETER
Accuracy .0015%

RANGES X1 to 1.901010 volts
X.1 to .1901010 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

To extend the voltage range upward, the National Bureau of Standards has designed a volt box, described in their research paper No. RP 1419, in which the various ranges are so selected that it is possible not only to have a highly accurate and stable box, but to cross-check the various sections and literally bootstrap one's self up to as high as 1500 volts, by means of only a stable voltage source and an accurate potentiometer.

Volt boxes of this type are inherently more stable and accurate than the ordinary volt box due to the large number of bobbins employed on the higher volt ranges, maintaining a constant watts-per-square centimeter for all the resistors involved. Also, these devices are provided with a guard circuit which eliminates the possibility of leakage causing an error at higher voltages.

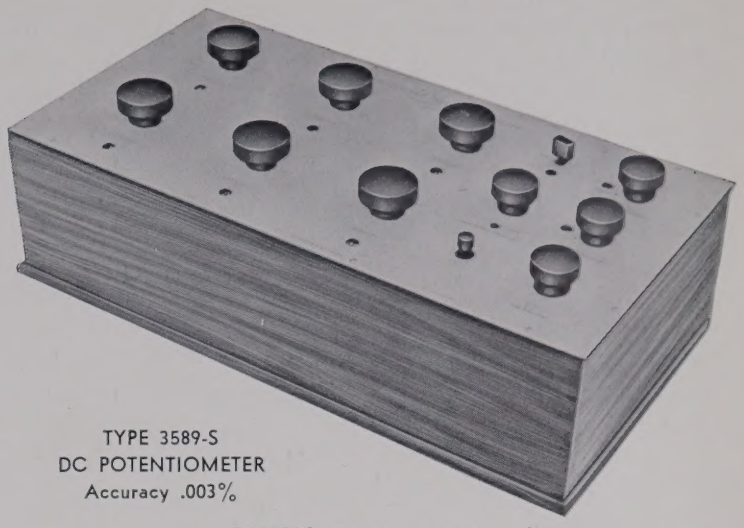
TYPE 9700
VOLT BOX
NBS Type



15 Ranges
.15 volt to 1500 volts
Accuracy .001%

Oil
Circulated
Temperature
Controlled
Oil Bath

The *COMMANDER* 9700 volt box and the *COMMANDER* 9700-A, reading to top voltages of 750 and 1500 volts respectively, are excellent examples of this type of volt box. Such volt boxes do not require Bureau certification in order to maintain working accuracies over long periods of time, because of the possibility of this self-check which is inherent in the design of the instrument. Hence, as far as voltages are concerned, a potentiometer of the types described will provide satisfactory extrapolation on down into the microvolt range from the standard cell voltage and the volt box will provide extrapolation up above this voltage to 1500 volts.



TYPE 3589-S
DC POTENTIOMETER
Accuracy .003%

RANGES X1 to .111110 volt
X.1 to .0111110 volt
Resolution 1 microvolt on X1 Range
.1 microvolt on X.1 Range

At this point, one additional factor immediately becomes pertinent. In extrapolating the voltage upward with the NBS type volt box, we have self-check provisions which can give us assured accuracies at the higher voltages. If we limit our choice of potentiometers to the *COMMANDER* type 9144, we have this self-same check provision built into the equipment allowing us to check the linearity of the main dials and standard cell circuits without recourse to any equipment other than another potentiometer with sufficient sensitivity to detect a microvolt and sufficient short-term stability to hold it during the course of a reading.

This second potentiometer does not have to have any accuracy or NBS checking of its own operation. The 9144 has built into its own circuitry all of the necessary switches and extra connections to provide complete external self-check procedures to assure the user of accuracy throughout its range without recourse to separate checks and, hence, any necessity for the potentiometer itself to go to the Bureau. To the best of our belief and knowledge, this 9144 is the only potentiometer of which this is completely true.

Now we reach the problem of extending our resistance ranges from possibly a single one ohm NBS standard which we had calibrated and certified at the Bureau. For this, one can use a Wenner Bridge or any one of several other devices to inter-compare resistors of similar values or resistors of nearby values.

We can ALSO use the *COMMANDER* 9144 potentiometer as a ratio device for checking of standard resistors. A unique feature of this potentiometer is inclusion in the standard cell side of the potentiometer positions for one volt, one-half volt, two-tenths volt and one-tenth volt. If, then, one sets up a common current through a known resistor and an unknown resistor and applies the potential from the known resistor to the nominal one volt position of the standardizing circuit on the potentiometer and the drop across the unknown resistor is applied to the normal EMF positions of the potentiometer, a balancing of the pot by means of the EMF dials will immediately indicate the exact ratio between the two resistors. These EMF dials can be direct reading then in resistance, requiring only the proper placing of a decimal point. This is true even though the standard resistor may have known corrections.

There is included a special set of red figures on the standard cell dial which reads from zero to plus or minus 50 parts per million. When this dial is used for setting in the necessary corrections to the standard, the main dials become DIRECT READING in absolute resistance.

By this method which has a comparative accuracy in the order of one part per million, ranges of resistance of from twice the known standard resistance down to well below one-tenth of the standard resistance can readily be compared. By this method, it is relatively easy to extrapolate in steps of not more than ten to one, in either direction, from the basic one ohm NBS standard. By this method we now can have working standards with a practically infinite range of resistance, a wide range of voltage and we still have not exhausted the possibilities of so universal a piece of test equipment as the *COMMANDER* 9144 potentiometer.

In order to extend the accuracy of our saturated standard cell bank out into the plant, we would normally use other saturated cells for the highest accuracy and for somewhat lower accuracies either the SRIC Model STV, or unsaturated standard cells. We need a means of comparing these to our saturated bank.

For this use, the *COMMANDER* 9144 makes an excellent standard cell comparitor. The simplest method of using this is to connect four circuits to the EMF terminals of the 9144 potentiometer through a 9145 thermo free switch. Connect to one position terminals of the standard cell to be measured and to the other three positions, three of the cells in our standard cell bank. By switching to any one of the three standard cells in the bank, the EMF dials are set to its known value and the current in the potentiometer balanced without recourse to the standardizing circuit of the potentiometer. For utmost accuracy, we then cross-check the two other cells of the saturated cell bank. Without restandardizing the operating current in the potentiometer, switch to the unknown cell to be certified, rebalancing by means of the EMF dials only. The value of the unknown cell is determined directly from the EMF readings. These readings are readily made to one microvolt directly from the dials.

If a *COMMANDER* 5214 galvanometer amplifier is used, preferably with its companion SR 21 secondary galvanometer, galvanometer sensitivity can be made sufficiently great that extrapolation between the one microvolt steps on the finest dial can readily be made to much better than a tenth of a microvolt. This resolution is very comparable with any other possible standard cell comparitor device and, of course, we have had to have only one single potentiometer to accomplish this.

It is obvious from the above descriptions that we consider the *COMMANDER* Model 9144 as the heart of a standards operation, because of its use as a potentiometer, as a resistor comparitor, as a standard cell comparitor and because of its self-check features. For those applications where you require its use as only a potentiometer on a full-time basis, then one should very well consider the 4363-D which is very nearly its equal as a potentiometer. If one has full-time usage for a straight resistance comparitor, then one of the Wenner comparitor bridges is slightly faster and more convenient. If one has full-time use for a standard cell comparitor, some of the specialized standard cell comparitors on the market are a little bit faster and more convenient for this operation.

Unless the standards department has sufficient work to keep three separate instruments in full time use, the 9144 is the logical choice. The 9144 doing all three jobs, will keep the small plant standards investment at a minimum and still keep complete coverage available. Also, because of its wide-range facilities, it becomes an excellent second device for the extremely well-equipped department.

For instance, if one had all three of the equipments mentioned — the potentiometer, the comparitor bridge, the standard cell comparitor — in order to have spares, one would need three separate spares. The 9144 would provide alternate facilities for any one of the three when required. In other words, we are enthusiastic about the possibilities of this instrument.

The combination of a 9144 potentiometer, a 5214 galvanometer amplifier, and SR 21 galvanometer for use with the 5214, an SR 4 galvanometer for use in the standard cell circuit for uses requiring simultaneous main dial and standard dial balance and a 9145 thermo free switch for switching inputs to the potentiometer constitute the heart of a complete standards set-up. The user of such equipment can then be assured of measurements to the highest degree of accuracy obtainable today.

These instruments are described in detail in our brochure on ELECTRICAL MEASURING STANDARDS, a copy of which is yours for the asking. Our Model STV standard volt is described in our general instrument catalog.

Current Sensitivity
up to
350,000 mm
per microampere

TYPE 5214

PHOTO CELL
GALVANOMETER
AMPLIFIER

TYPE SR-21 GALVANOMETER
Sensitivity .002 microamperes per mm